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# REPORT FOR 1906.

ON THE

# LANCASHIRE SEA-FISHERIES LABORATORY

AT

THE UNIVERSITY OF LIVERPOOL,

AND THE

# SEA-FISH HATCHERY AT PIEL.

DRAWN UP BY

Professor W. A. Herdman, D.Sc., F.R.S.,

*Hon. Director of the Scientific Work,*

Assisted by Mr. Andrew Scott, A.L.S., and
Mr. James Johnstone, B.Sc.

*WITH ILLUSTRATIONS.*

LIVERPOOL:
Printed by C. Tinling and Co., Ltd., 53, Victoria Street.
1907.

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# REPORT on the INVESTIGATIONS carried on during 1906 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

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(With plates, charts and figures in the text.)

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## INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

During 1906 the system of quarterly reports which was referred to in the Introduction of the last Annual Report has been continued with the view of bringing the more important matters dealt with in the laboratory before the notice of the Scientific Sub-Committee with as little delay as may be, and has also served to keep the Committee generally better informed as to the progress of the scientific work.

The Board of Agriculture and Fisheries have sent various specimens to the Liverpool laboratory to be examined. Their Inspectors have visited the laboratory

more than once during the year, and a report on the work carried out has been furnished, at their request, to the Board.

A considerable part of the work is of a routine nature and does not differ much from that reported on last year. Mr. Scott has been chiefly occupied at Piel with flat-fish hatching, with the fisheries classes, and with making as complete an estimate as possible of the minute floating life in the sea all over the district. Mr. Johnstone's chief work has been, as usual, the conducting of the fishermen's classes at Piel, the bacteriological examination of samples of shellfish, as required, and the investigation of the parasites and diseases of fish in the Liverpool laboratory. The marked fish experiments, the Hensen net experiments and the collection of the hydrographic samples have also occupied part of the time of both Mr. Johnstone and Mr. Scott. Some of these lines of inquiry will be commented upon now, and others will be found discussed more fully in the sections of the report that follow.

## Flat-Fish Hatching.

Mr. Scott's report shows that nearly 14 millions of plaice and flounder fry were distributed last season. As I have already pointed out on previous occasions, our numbers in this output do not, and cannot, increase. The really quite inadequate provision of tanks at Piel is strained to the uttermost, as many plaice and as many flounders are accommodated as can possibly be kept healthy. I am satisfied that Mr. Scott is doing all that can be done in the matter, and that until a spawning pond and a better equipment of hatching tanks is provided there is no hope of increasing the output.

I may remind the Committee that in the Port Erin Hatchery we have a second establishment adding annually

to the stock of young flat-fish in the Irish Sea. Last spring over five million plaice fry were hatched from six million eggs and were successfully set free in the open sea to the south and west of the Isle of Man.

As before, a certain number of the larvæ have been left throughout the summer in the open-air spawning pond at Port Erin and reared through their metamorphosis into young plaice. It is very interesting to note that of these young fishes, all of the same age, while those left in the larger pond, under more natural conditions, had attained by September (say five months' growth) a size of up to nearly five inches in length (the average of 12 being $3\frac{1}{2}$ inches), a few that had been placed on exhibition in the Aquarium in a white enamelled basin, although regularly fed, in the same time grew to only one inch. A few thousand put in the smaller western part of the pond were sampled on October 3rd, 162 days after hatching. Twelve taken at random varied in length from $1\frac{1}{8}$ inch to $2\frac{7}{8}$ inches, the average length being $1\frac{3}{4}$ inch.

The classes for fishermen at Piel laboratory have been held as usual, and with the usual success. The details are given in Mr. Scott's Report below.

### Sea-Fish Hatching in Norway.

I print two interesting statements sent to me by Captain Dannevig and Mr. K. Dahl, dealing with the supposed results of adding artificially hatched cod larvæ to certain Norwegian fjords. These investigators not only write from very different points of view, but unfortunately they do not deal with exactly the same series of observations, so that it becomes difficult to compare their results, and, in fact, on a superficial examination it might be supposed that no correspondence could be traced between

the two series of statements. If, however, we remove the additional observations dealt with by Mr. Dahl, and which were apparently not a part of the joint enquiry agreed upon, some facts remain in common, although they may be interpreted in different ways. For example, Dannevig shows that in 1903, before his Flodevigen larvæ were liberated, the Sondeled Fjord yielded 426 cod larvæ (to over 100 hauls of the seine =4 per haul), while the two following years (after the planting of the fry), averaged, gave 1,328, or about 13 per haul. Removing the July-August observations, which do not appear in Dannevig's experiments, these numbers agree with what is shown in Dahl's table, and indicate an increase to about three times the amount. In the case of the Hellefjord, where smaller numbers were dealt with, the correspondence of results is not so clear, and some further explanation is perhaps necessary; but, averaging both localities, Dannevig shows the increase after planting to about double the quantity, which is represented graphically in his diagram. Captain Dannevig, of course, attributes the increase to the liberation of the artificially hatched larvæ, while Dahl from his additional observations with tow-nets, &c., comes to the conclusion that the cod eggs and larvæ naturally present are so affected in their abundance and distribution by currents in the water which vary from year to year, that the fry added can have no appreciable effect, and that such increases or decreases as may be noted from year to year are due to natural reproduction and hydrographic influences. The impression produced by reading these two papers is, I think, that the observations are still too few to lead to any sure conclusions; but it may be useful to point out that, even if Dahl's interpretation is correct, it does not follow that Dannevig's operations are useless. If the addition of 50

or 60 millions of young cod adds to the stock in that fjord, the benefit may be great even if from other causes the average per haul in the following year shows a decrease. An addition has been made to the natural stock of fry—whatever that is—and that may well have a beneficial effect upon the future population whatever, as the results of various factors, that may come to be.

### Plankton Investigations.

During the past year a larger number of plankton gatherings have been obtained by tow-nets than ever before, and these have been very carefully examined by Mr. Andrew Scott. Four hundred gatherings in one year from a limited area like the Irish Sea ought to give useful information, and the value of the series is increased by the fact that in so many cases we have gatherings taken from different parts of the area on the same day, amounting to practically simultaneous observations. The advantage of having several centres of work in the district —the steamer, the bailiffs, Piel and Port Erin--from which observations can be taken is obvious in an enquiry like this; and Mr. Scott's lists and tables given below will be seen to be an interesting contribution to a subject that is still imperfectly known. Before any far-reaching conclusions can be drawn from plankton gatherings it is clear that we must be sure what it is that our nets are catching, and how far the samples caught on different days or at different localities or with different nets are comparable, and can be said to be representative of any time or place. With a view of testing such points I chartered a small steamer for two months last summer and took almost daily gatherings, with several different kinds of tow-nets, during August and September. In all, about 80 samples were collected in 40 days, and the main result is to show a

puzzling diversity, which indicates that further work is necessary.* I hope to continue this work myself from a small steam-yacht during the coming spring and summer. In addition to the equipment previously used I have recently obtained a Nansen closing deep-water tow-net with which observations will also be taken.

Dr. Travis Jenkins has recently arranged to permit of the steamer taking periodic trips along a fixed line for the purpose of obtaining gatherings with the large Hensen quantitative net. These trips will take place monthly, the line of stations is from Piel Gas buoy to the Great Orme Head, and Mr. Scott will carry on the work. The series was started in January, 1907, and the second trip is now taking place.

### Hydrographical Observations.

The scheme of hydrographic observations which was proposed in the Introduction to the last Annual Report was duly sanctioned by the Committee, the necessary apparatus was obtained, and the practical work was started in summer. The observations are carried out by Mr. Johnstone on the steamer, and the samples of sea-water obtained are analysed in the laboratory by Dr. Basset, to whom we are very much indebted for the time and trouble he is kindly giving to the work. It is too soon yet to come to any conclusions, so I merely place on record the following list of observations made:—

Three cruises were made during 1906:—

(1) 4-5 July, 1906.
(2) 18-19 Sept., 1906.
(3) 13-14 Nov., 1906.

* A fuller account of these observations was given in an address delivered to the Biological Society, and published in the Annual Report of the Liverpool Marine Biology Committee in December. I do not repeat the information here because I am convinced that further work is required and that I shall be able to give a better account of the whole subject by waiting till next year.

On each cruise two lines of stations were worked:—

(1) Piel Gas Buoy, Walney Ch. to Maughold Head.
(2) Calf of Man to Holyhead.

Four "stations" were worked on each line:—

(1) 6 miles N.W. from Piel Gas Buoy.
(2) 15 ,, ,, ,, ,,
(3) 24 ,, ,, ,, ,,
(4) 32 ,, ,, ,, ,,

and (5) 7 miles S. by W. from Calf of Man.
(6) 16 ,, ,, ,, ,,
(7) 25 ,, ,, ,, ,,
(8) 33 ,, ,, ,, ,,

It was decided that observations should also be made in Carnarvon and Cardigan Bays during the third cruise, but bad weather prevented these from being carried out.

## Bacteriological Work.

A good deal of Mr. Johnstone's time has been occupied with questions of sewage contamination of shell-fish beds on the Lancashire and North Wales Coasts. The investigation of such cases, both on the ground, where adequate samples have to be taken, and also subsequently, as a matter of bacteriology in the laboratory, is of very great importance and some difficulty. The responsibility attaching to such work is very great, because of the possible danger to public health on the one hand, and the possibility of injuring a prosperous industry on the other. The Scientific Sub-Committee have had several carefully considered reports from our laboratory during the year, and the results of Mr. Johnstone's examination of the Morecambe and the Conway mussel beds are given below.

## Other Work.

The experiments with marked fish are fully discussed in Mr. Johnstone's article below, and the other sections of this report dealing with the Parasites and the Food of fishes, the Ichthyological notes and the Faunistic notes explain themselves and require no further comment.

As the present winter is a critical time in the history of sea-fisheries research in this country—on account of the approaching termination of the five-year period of the International North Sea Investigations, and the hope that on the conclusion of that work Government may be willing to subsidise similar work on other parts of the coast—I have thought it desirable to draw up, for the information of the Committee, a statement of the present situation, as it now appears to me. I print this article on "Sea-Fisheries Research in England" with the view, not of criticising any particular plan or piece of work, but of pointing out that the present juncture seems to give an opportunity of uniting all interests round the three coasts of England in a comprehensive national scheme.

W. A. Herdman.

Fisheries Laboratory,
University of Liverpool,
*February 5th*, 1907.

# SEA-FISHERIES RESEARCH IN ENGLAND

(A statement bearing on the present situation).

By W. A. Herdman, F.R.S.

The position of this country in connection with Sea-Fisheries investigations at the present juncture is most interesting; and the decision which H.M. Government will be called upon to make, early in 1907, as to the measure of official recognition, control and support to be given to such investigations on different parts of the coast will be of unusual importance, since it cannot but have a profound effect upon future work and knowledge bearing on fishery questions. In the recent history of the subject the only period approaching the present in interest and importance is the winter and spring of 1901-2. It may be useful to recall that at that time, five years ago, two quite unusual events had taken place. One of these was the announcement, on January 31st, that the then Government had given its adhesion for a period of several years to the International Scheme of North Sea Investigation; and the second was the presentation to Parliament, and subsequent publication, of the Report of a Committee of Government Officials, Fisheries Experts, and Zoologists, to whom had been referred the whole question of scientific investigations in connection with British Sea-Fisheries.

This latter body, the "Ichthyological Research Committee," was appointed by the President of the Board of Trade (the Government Department which at that time included Fisheries) in August, 1901, and meetings for the examination of witnesses and discussion of results were held during the twelve months to

September, 1902. The Report of the Committee, which was issued as a Parliamentary paper about the end of the year, recommended a comprehensive National Scheme of investigation centring, as regards England, in the Government Department, co-relating and uniting the energies of the various administrative and investigating bodies, and giving the necessary support to a marine laboratory on each of the three coasts.

Legislative action upon these various recommendations was, however, postponed, because the Government had meanwhile become engaged to participate for a period of years in the International scheme of investigations; but the Report of the Ichthyological Committee was received with marked approval by most, if not all, of the Sea-Fisheries Authorities of England and Wales; and in answer to representations made at successive annual statutory meetings, the President of the Board (formerly of Trade, latterly of Agriculture and Fisheries), in the chair, has stated on the various occasions that at the conclusion of the limited period for which the International work had been guaranteed, the question of a National Scheme would be considered, and the claims of the Local Sea-Fisheries Districts would then receive attention from the Government.

For example, Earl Carrington, the present President of the Board of Agriculture and Fisheries, at the meeting in the House of Lords on 14th June, 1906, after expressing his sympathy, stated that he "would leave no stone unturned" in trying to get from the Treasury some money for such a National Scheme as was desired, and he ended by appealing to the Local Authorities present to give him all the support in their power when the time came [see Blue-book, Cd. 3063, p. 10]. Within the next few weeks is clearly the

proper time for compliance with Lord Carrington's request, since the five-year period of the International work expires in July, 1907, and if any part of the money then set free is to be secured for Local Sea-Fisheries investigation it ought to be included in the estimates which will shortly be prepared for Parliament. Under these circumstances, it seems desirable that a somewhat detailed statement should be made, avoiding as far as possible critical and controversial matters, but setting forth plainly the present position and the alternatives that are now placed before the country.

## The International Scheme.

Some years ago a group of distinguished foreign meteorologists and biologists put forward a scheme for international co-operation in the hydrographic and biological investigation of certain North-European seas (North Sea, Baltic, Norwegian Sea, &c.), in the hope that the data thus acquired might throw light upon weather prognostication in the interests of navigation and commerce (a matter of some importance to the more northern nations) as well as upon the conditions and prospects of the fishing industries in those seas. The matter was taken up by the Swedish Government, and on their invitation Great Britain, Germany, Russia, and other countries bordering upon the North Sea and the Baltic, agreed to participate in the investigation and to contribute towards the expenses of a central organisation.

Great Britain, however, only consented in the first instance to take part in the work and contribute to the expenses for a period of three years; but later on the time was extended so as to complete the five

years for which other nations were pledged, but at the same time it was made clear to the International Council that our Government did not contemplate any further continuance of the work. ("The delegates are requested to impress upon their foreign colleagues that it is not the intention of His Majesty's Government to participate in the investigations on the present footing after 22nd July, 1907."—Blue-book Cd. 3165, p. 9).

The cost has been great—the British share of the total expense amounted to about £70,000, or £14,000 per annum, of which £5,500 was allotted to work done off the Scottish Coasts and £5,500 to that on the East and South Coasts of England—the remainder being required for expenses of administration and the central organisation. No part of the money was expended on Ireland, nor on the Western Coasts of England and Wales. The Scottish portion of the work, it was arranged, should be carried out by the officials of the Fishery Board for Scotland under the Scottish Office; and the English portion by the Marine Biological Association, a well-known scientific body controlled by a council of between 30 and 40 members, under the presidency of Professor Ray Lankester, and having a large laboratory and headquarters at Plymouth, with a smaller branch establishment at Lowestoft for the special purposes of the International work.

The Local Sea-Fisheries Committees around the coasts of England had no part in the work, nor had the Government Department chiefly concerned in the subject (the Board of Agriculture and Fisheries).

The International investigations have been controlled by a Council ("Conseil Permanent International pour l'Exploration de la Mer"), the Executive of which is a "Bureau," having its seat at Copenhagen and its Central

Laboratory at Christiania. The Bureau consists of an inner circle of three ordinary members, viz.:—

Dr. W. Herwig (Germany) as President,
Dr. O. Pettersson (Sweden) as Vice-President,
Dr. P. P. C. Hoek (Holland) as Secretary;

and an outer circle of four extra-ordinary members,

Capt. Drechsel (Denmark) as Hon. Treasurer,
Dr. F. Nansen (Norway), Director of the Laboratory,
Prof. O. von Grimm (Russia), and
Prof. D'Arcy W. Thompson (Scotland).

Thus Great Britain is not represented on the inner circle, and England has no representation even on the outer body, although England's interests in the North Sea Fisheries are admitted to be paramount.

The International investigations have been carried on with energy and enthusiasm for the last four and a half years, and the reports that have already appeared—including "Rapports et Procès-verbaux," "Bulletins des Résultats," "Publications de Circonstance" issued by the "Conseil Permanent International," and the Blue-books and other publications of our own and other Governments—form an enormous body of literature, containing much that is of the greatest interest to scientific men, and some of which will, no doubt, one day find its place in a scheme of knowledge that is useful in connection with practical fisheries questions.

It is scarcely necessary to point out that a clear distinction can be drawn between a scheme of investigation (1) as a piece of pure scientific research, and (2) as a practical enquiry which will solve within a given time and by given means questions of importance to particular industries. Of the interest and importance, to science, of the International work as a piece of pure research there ought to be, and probably there is, no

doubt. We must all be in sympathy with the work from that point of view. It is oceanographic research of the most desirable and fascinating kind, which is bound to yield qualitative results of great interest to biologists—and probably also to hydrographers. But there is the greatest difference between (1) such qualitative results which add certain new facts to science, and in regard to the economic importance of which all that can be said is that each and every scientific fact will some day find its application and may then become of commercial importance to mankind, and (2) immediate quantitative results given as the outcome of investigations directed to particular practical problems. Viewed as the former, the International results are valued contributions to science; the facts are useful whether few or many, whether they establish any definite principles or not, and the conclusions put forward are welcome if regarded only as scientific speculations which stimulate and suggest and may lead eventually to definite proof. It is when put forward as quantitative results directly applicable to practical questions that grave doubts arise as to the adequacy of the methods to solve the problems and as to the sufficiency of the observations to justify the economic conclusions.

I have no desire to assume a critical aspect, or to try to find defects in the International or any other useful work. All such investigations must have defects, and I much prefer to appreciate the valuable contributions to scientific knowledge made by the International Council: they have added greatly to the sum of our data in the Hydrography and Biology of the North Sea. If those who prosecute and those who support this investigation will declare that they regard it as scientific research undertaken jointly with foreign savants with the object

of acquiring certain scientific data—which may, or may not, have a bearing upon fishery questions—then I, for one, will cordially approve of the enlightened action of our Government in endowing scientific research to that extent. But the British Delegates at the International meetings have made it quite clear that our country took part in the scheme with the expectation of obtaining practical results in the fixed period of years.* How unlikely it is that any such results will be obtained by the methods, in the time, can only be realised by those who have had considerable experience of the irregularity of distribution of fish and other living things in the sea, and the difficulty of obtaining samples that are truly representative of an extensive area.

It is obvious that if we are to have the benefit that was promised from international co-operation, any conclusions arrived at should be put forward with the full authority of the International Council, and as the deliberate opinion of the united wisdom of the experts; but it is evident from the published results that a considerable amount of difference of opinion already exists. In both the hydrographical and the biological sections we find the conclusions of some of the investigators rejected by their fellow-workers [see Blue-book, Cd. 3165, p. 6, and paragraph 9 on p. 7; also Cd. 2966, p. 47]. As a matter of pure science this is of no great importance, it may be helpful rather than harmful, since it tends to promote research and discovery; but when it is a question of conclusions that may be applicable to the industries

* In the Report of the Christiania Conference, in 1901, we are told, under the heading "Guarantees of Practical Results," that it was agreed "that the work of summarizing the practical results of the scientific explorations should not be left to the end of the five years' period, but should be undertaken from year to year. Consequently, by now we ought to have the "practical results" of the first four years in our hands.

the case is very different. If any of these conclusions are liable to be made a basis for action by the Government or by any Fisheries Authority, they ought obviously to be subjected to the same open discussion and free criticism as would take place in the case of an ordinary scientific theory. This will, no doubt, be the case eventually with the International results, but in the meantime it is most undesirable that conclusions or opinions expressed authoritatively should be put forward unsupported by the detailed observations on which they are based.

### The Ichthyological Research Committee.

At the same time that Great Britain undertook to participate for a limited number of years in the International investigations, the Committee above referred to was sitting at the Board of Trade charged to report "as to the best means by which the State or local authorities can assist scientific research as applied to problems affecting the fisheries of Great Britain and Ireland." This Committee, which reported in 1902, consisted of four representatives of Government departments (the late Mr. S. E. Spring-Rice, of the Treasury; Mr. Pelham, of the Board of Trade; Sir. C. Scott-Moncrieff and Sheriff Crawford, of the Scottish Office); and four zoologists or fisheries experts (Mr. Walter E. Archer, of the English Fisheries Department; the Rev. W. Spotswood Green, of the Irish Fisheries Department; Professor J. Arthur Thomson, of Aberdeen; and Professor W. A. Herdman, of Liverpool).

After the detailed examination of many witnesses representing science, the fishing industries, and all other interests concerned, and some discussion of results, the four experts were requested by their colleagues to

draw up a Memorandum as to the relations of the International scheme to the most pressing fishery problems and the methods to be adopted in the solution of such problems. This Memorandum was adopted by the Committee and is printed on p. xxii. of the Report (Blue book Cd. 1312).

If the argument in this Memorandum of the Ichthyological Committee is correct, grave doubt is cast upon the validity of any results which might be obtained solely by methods proposed in the "Christiania Programme"—the revised or second official programme of the International work. It is evident from an examination of the official publications of the International Council that some such doubts must at a later date have occurred to those engaged in the work. For example, in August, 1902, at the first meeting held after the memorandum above referred to had been presented, the Council resolved that it was not possible to undertake the biological portion of the "Christiania Programme" in its totality, and decided to restrict the investigation to certain problems [Cd. 1313, p. 102]. Again, in 1904, it was recognised that the methods hitherto adopted were inadequate for the solution of these problems, and the instructions to the British delegates [Cd. 2966, p. 32] caused still further alteration in the International programme. Then, in 1905, the quarterly "seasonal cruises" (in February, May, August and November), which were a very fundamental point in the original scheme, and which had been criticised in the Report of the Ichthyological Committee, were apparently recognised as being inadequate and were supplemented by more frequent observations [Cd. 2966, pp. 54, 172, 174, 175 App. B, also Cd. 3165, p. 14].

Thus the progress of events during the last four

years has, on the whole, tended to show that the criticisms put forward in the Report of the Ichthyological Research Committee were well founded, and served to indicate the direction in which the International Scheme of work has required to be modified. Under these circumstances, we turn now with the more confidence to the constructive portion of that Committee's Report in order to enquire how far the recommendations then made will meet the needs of the situation at the present juncture. The Committee recommended a National Scheme of fisheries research and organisation, into the constituent elements of which they entered in considerable detail. This scheme provides what has long been felt and often expressed as a great need in England, viz., a Central Fisheries Board, having at its command laboratories, vessels and scientific men on all the coasts, and it also endeavours to ensure the sympathy and utilise the energies of the District Committees, by giving them adequate representation on the Central Body and by delegating the work on the several coasts to the local investigators.

The points dealt with in the Report are (1) Statistics, (2) Expert Staff, (3) Laboratories, (4) Vessels, (5) Central Authority, and (6) Co-operation with Scotland and Ireland; and the recommendations under these heads may be briefly summarised, with comments, as follows:—

(1) Statistics.—The Committee insist upon the necessity for much fuller and more accurate statistics as to the results of the commercial fisheries than are now supplied. Returns must be obtained from the masters of fishing vessels, and it is very desirable that full returns of all fish caught, giving the localities and other particulars, should be made compulsory.

The official system of collection of fisheries statistics has been improved at many ports since 1902, but further

development around the coast generally is much to be desired.

(2) EXPERT STAFF.—In the first place a staff of trained assistants is required at the principal fishing ports to deal with the returns obtained from the boats, to inspect the catches landed and to select samples for further examination. Certain observations can be made and certain particulars noted by such assistants carrying on statistical work at the ports, but it is not suggested that they need be laboratory biologists. Then, secondly, the samples selected, along with the statistical and any other information, should be sent for more detailed examination to the recognised marine laboratory of that coast, there to be dealt with by the Director and his scientific assistants.

(3) LABORATORIES.—The Ichthyological Committee point out that "the fishery interests of the East Coast, the South Coast and the West Coast of England, respectively, are, to some extent, distinct," and they propose that these three coasts should be treated independently, each having it own marine laboratory, staff of workers, surveying vessel, and representatives on the Central Authority. It is recommended that, if possible, arrangements be made so that (1) the Marine Biological Association Laboratory at Plymouth be officially recognised as the headquarters for scientific fisheries work on the South Coast, say from the Estuary of the Thames to the Bristol Channel; (2) that the Liverpool Marine Biological and Fishery Laboratories be similarly the centre for work on the West Coast ; and (3) that a laboratory be established to perform similar functions on the East Coast. If the new Marine Biological Station which is now being erected at Cullercoats, in the Northumberland Committee's District, had then been in existence, there can be no doubt that the

Ichthyological Committee would have recommended that that laboratory should be recognised as the centre for work on the East Coast. It is possible, also, that, under

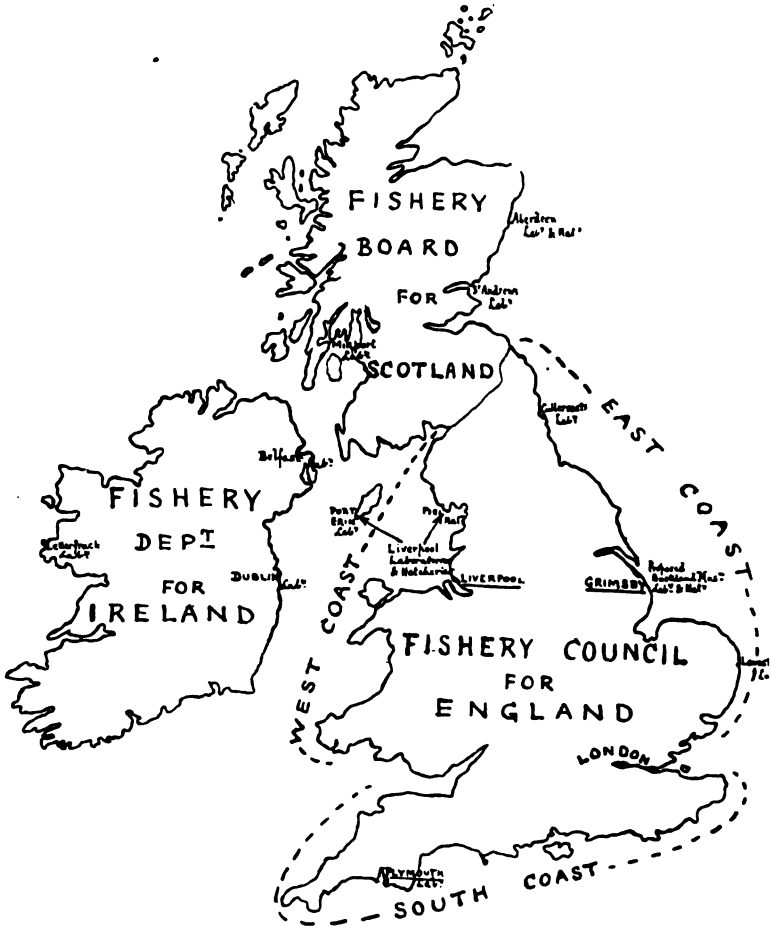



FIG. 1. Sketch Map of the British Islands, for the purpose of indicating the position of the chief marine laboratories and sea-fish hatcheries, and the proposed division of the coast of England into three great fisheries districts—The East coast, the South and the West.

the conditions now existing, the recommendation might have been added that the Lowestoft Laboratory should be

taken over, if that is possible, from the Marine Biological Association, and should be the home laboratory of the Fisheries Department of the Board of Agriculture and Fisheries, in order to furnish the Government Department with the laboratories, experimental tanks and scientific assistants, without which the officials cannot be expected to carry on original investigations.

On the other hand, if the view be held that the Government Department should not itself undertake any actual marine investigations, but should delegate such work to the different laboratories round the coast, a natural division of the area would be for the Marine Biological Association, with its laboratories at Plymouth and Lowestoft, to conduct the explorations from Cornwall to the Wash, while the District Committees North of that point, with the laboratory at Cullercoats, would undertake the remainder of the East Coast. The exact details of such divisions are not of prime importance, the essential point being that the Ichthyological Committee in making their recommendations in regard to laboratories for the three coasts made use to the fullest extent of existing institutions.

(4) VESSELS.—Each of the three coasts, it is proposed, should have a research or surveying steamer of the type of a modern steam trawler, especially fitted up for scientific investigations and carrying on its work in connection with the laboratory of that coast.

(5) CENTRAL AUTHORITY.—The Ichthyological Committee recommend the formation of a "Fishery Council for England," consisting of representatives of (*a*) the Board of Agriculture and Fisheries, (*b*) the local Sea-Fisheries Authorities of the three coasts, and (*c*) the scientific men in charge of the three marine laboratories. This Fishery Council would be, to some extent, analogous

to the Fishery Board for Scotland, but more suitable in other respects to England, where strictly local fisheries are more common than in Scotland, and where local needs have to be more closely studied. The Council would, it is hoped, be so representative as to unite the various fisheries' interests and ensure the co-operation of the different organisations, local and central, now working at fishery problems. It is suggested that the Fishery Council should meet monthly, or more often as occasion may require, under the Board of Agriculture and Fisheries, to formulate and control schemes of investigation, to receive reports on work done on the three coasts and co-relate observations, to recommend the allocation of grants to the laboratories, and, generally, to report to Government, through the Board of Agriculture and Fisheries, on the needs and results of the work carried on by the steamers and the laboratories.

INTERNATIONAL CO-OPERATION.—In order to secure uniformity of action between the Fisheries organisations in England, Scotland and Ireland, to prevent overlapping of areas and of investigations, and to arrange as to any sub-division of work between the three countries, or with foreign nations, the Ichthyological Committee recommend that quarterly conferences should be held between representatives of the Fishery Council for England, the Fishery Board for Scotland and the Irish Fishery Department. "The meetings of this conference would give an opportunity to the members of the three Central Authorities to compare notes, to obtain information as to what is being done in the three countries, and to make suggestions to the three Central Authorities as to what particular work should be undertaken by each" (Report, p. xv.). It is only to this extent—Quarterly Conferences—that the Ichthyological

Committee have considered it practicable to constitute one Central Fisheries Department for the United Kingdom. We may quote finally paragraph 39 from the "Concluding Observations" of the Report:—

"The Committee believe that by carrying out these recommendations the State would recognise, co-relate and control the work of the existing independent organisations in the United Kingdom, and would build up a scheme of Fishery Research of a thoroughly practical character, centring, as regards England, in the Board [of Agriculture and Fisheries], and, at the same time, in intimate contact with the fishing trade, the District Committees and the scientific laboratories round the coast."

### The Present Situation.

The adoption of these recommendations made in 1902 by the Ichthyological Committee's Report would, it is believed, satisfy the wishes and claims of the District Committees on the East and West Coasts, but it seems improbable that that course would satisfy the Marine Biological Association, and it is quite incompatible with a continuance of the International work as at present carried on. It seems doubtful, however, whether the officials of the Marine Biological Association desire that the International work should be continued under its present organisation. The Council of the Marine Biological Association have recently issued various circulars and reports, and have organised a deputation to the Chancellor of the Exchequer, asking H.M. Government to give them control, not merely of the whole amount they have been administering annually in the North Sea investigations, but also of an additional £2,000 a year for the Plymouth Laboratory, making a total annual grant of £8,000, with no limit of time specified. It is very

difficult, from these reports and the speeches of prominent members of the Council, to understand exactly what are the intentions or wishes of the Marine Biological Association in regard to the International Council and Bureau. They ask quite definitely to be allowed to continue the International investigations; but a passage in the speech by the Chairman of the M.B.A. Council suggests that they are contemplating the severance of their present connection with the International Council. If that is the case, it is surely of primary importance to all concerned in the discussion of these questions to know under what organisation they propose to work. If they do not desire to continue under the direction of the "Conseil Permanent International," are they prepared to adopt the recommendations of the Ichthyological Research Committee to such an extent as will satisfy the claims of the Sea Fisheries District Committees of the East and West Coasts, or is it their intention to claim all the money that has recently been expended by England on the International work, and such additional grant as the Government may give, to spend after July on their own work under their own organisation, in independence alike of the International Council and of the constituted Sea-Fisheries Authorities around the coast? Surely their position in this matter should be made quite clear before their claim to the administration of the whole of the English portion of the International fund can be discussed.

In one of the circulars that has appeared during the winter, it was suggested that the M.B.A. Council might be increased by allowing the Board of Agriculture and Fisheries, the National Sea Fisheries Protection Association, and the different Sea-Fisheries Committees, who have established marine laboratories for scientific

research, and, if necessary, other bodies concerned, the right to nominate one or more members of Council.

It must be pointed out that although this may seem to be offering an opportunity to Sea-Fishery Committees of participating in the regulation and administration of Sea-Fisheries research under their scheme, it is not doing so in any real sense or on an adequate scale. The Council of the M.B.A. consists of about 38 members (including the President and Vice-Presidents, who have presumably a right to sit on Council), so that unless a considerable number of representatives of, say, the Government department on the one hand and the Local Sea-Fisheries Authorities on the other, were added, so that all elements were fairly balanced, no real power would be given. But such a greatly enlarged Council would be unwieldy and impracticable; in fact, the Council of the M.B.A., as it stands, is too large a body, besides being unsuitable in other respects, for such specialised work as is contemplated.

The Marine Biological Association is a distinguished Scientific Institution, one of the primary purposes of which is the promotion of research in pure science and the higher education of young Zoologists from the Universities. Academically it holds a high position and its educational value in pure science might be of national importance. It is on those lines that, in the opinion of some of its own members and loyal supporters, it ought to develop rather than in connection with the fishing industries. As a scientific and educational institution it is worthy of all possible encouragement and support, and it is to be hoped that H.M. Government will give a liberal subsidy to the Plymouth laboratory and other similar institutions for purposes of research in pure science.

But with the view of collecting, examining and co-ordinating such scientific researches at different centres and of applying them to specific fishery problems, and of making use of the money set free by the termination of the international work and such other funds as H.M. Government can devote to this important national object, it is essential to have a small working body of experts such as was recommended in the Report of the Ichthyological Committee—men who have been, and are, actively and sympathetically in touch both with the various fishing industries and the various methods of scientific research that can be applied to them. As examples of such experts may be taken Prof. McIntosh and Dr. Fulton, in Scotland; Mr. W. S. Green and Mr. E. W. L. Holt, in Ireland; and Mr. Walter E. Archer, in London. The academic Zoologists on the Council of the M.B.A. are all eminent men in their own special lines of research, but would, most of them, I hope, be unwilling to lay claim to expert knowledge on fishery problems.

It is, surely, unfortunate in the interests of science that the Council of the Marine Biological Association should have recently appealed to scientific men in general at the Universities to sign a petition addressed to the Lords Commissioners of H.M. Treasury in support of the work carried on by the International Council and its continuance in the hands of the Marine Biological Association. It is probable that some, at least, of the more or less distinguished Zoologists, Botanists, Geologists, Physiologists, Pathologists, Astronomers, Chemists, Mathematicians and Anthropologists who have lent their names for this purpose have done so with very imperfect knowledge, if any, of the methods and results of the international work, and very possibly in complete

ignorance of the other side of the case as represented by the Local Sea-Fisheries Committees.

## District Committees.

The administration of the Sea-Fisheries around our coasts is now entrusted to District Committees, who, under the Board of Agriculture and Fisheries, have large powers in regard to the supervision, regulation and promotion of the industries. Most of these Committees have undertaken some investigations, and a few of them have done much. They have secured the advice and assistance of scientific men, have helped in the establishment of marine laboratories, and have expended considerable sums upon investigations, both by special steamers and otherwise.

It would, in my opinion, be a fatal mistake to do anything that would tend to discourage such excellent local effort or to divorce administration from scientific investigation. All sound regulation of the Fisheries must be based upon accurate and detailed investigation. As the administration has to be applied locally, the investigation must be conducted locally. Every part of the coast, every shellfish bed, has its own problems. It is impossible to apply general principles or results obtained elsewhere without an intimate knowledge of the local conditions. The Sea Fisheries Committees which have been conducting such local investigations have a strong claim, not, perhaps, to be relieved entirely of the expense of this necessary work, but to receive a substantial contribution from the national purse. The local effort has in some cases been very considerable, funds have been raised, services have been given gratuitously and the work has been carried on energetically and successfully. There is no reason to suppose that the local subsidies will

fail, but they ought to be largely supplemented. The District Committees have been urging their claims for a grant from the Treasury for at least five years, and have received many assurances of sympathy and of ultimate substantial help.

The present juncture seems thus to afford an opportunity, such as has not previously occurred, of formulating a comprehensive scheme which will deal with all parts of the coast and unite all interests. Anything approaching to a monopoly in science is most objectionable. There cannot be a monopoly in work, so there ought to be none in State recognition and support. The North Sea investigations are welcome additions to science, the work of the Marine Biological Association is worthy of all the support that can be given both by scientific men and by the Government, but neither of these organisations covers the whole ground, and any scheme which does not embrace the three seas of England and utilise to the full the various laboratories and Fisheries Authorities around the coast, more or less on the lines of the Ichthyological Committee's Report, will fail to solve the present problem of Fisheries research in Great Britain.

## SEA-FISH HATCHING AT PIEL.

By Andrew Scott.

The results of the hatching work in the spring of 1906 are very similar to those obtained in previous years. The present accommodation for adult fishes is always strained to the limit of safety. Any marked increase in the output could, therefore, only be secured by considerable additions to the existing tanks.

The first eggs were observed on February 17th, but no fertilised ones were obtained till March 14th. The spawning lasted for practically two months. During that time fourteen millions of flounders' eggs were collected and one and a half millions of plaice eggs. The incubation of the eggs was carried on in the usual manner in the Dannevig apparatus, and yielded nearly fourteen millions of fry. The fry were liberated at intervals, well out in Morecambe Bay. It has been customary to set free the parent fish in the Barrow Channel at the end of each hatching season, but the fate of these fish has always been unknown. At the end of the hatching season in 1905 Mr. Johnstone marked some of the large plaice from the tanks and set them free between Lancashire and the Isle of Man. None of these have been recovered. Another attempt to find out the movements of the fish was made by marking some of the flounders in 1906. These were set free outside the Barrow Channel. A few of the marked flounders were recaptured by fishermen and returned to us, and are dealt with by Mr. Johnstone in his report on fish marking. During the autumn of 1906 the local

fishermen reported that several very large plaice had been captured in the Barrow Channel. The sizes of these fish far exceeded those of any flat-fish they had previously taken. The men suggest as a very probable explanation that they were some of our liberated plaice. Capt. Wright also secured one or two of these large fish while trawling for flounders for the tanks. It is quite possible, then, that the large plaice set free at the end of each season remain in the vicinity.

When selecting adult plaice for the tanks we depend largely on their size, and hitherto all under fourteen inches in length have been rejected. This size is probably a good average one, but it is evidently not always the minimum even for females. This was clearly demonstrated in the spring of 1906. In March, when out with the "John Fell" collecting material for the classes, two mature female plaice were captured in the same haul. One of these fish was nineteen and a half inches long, and the other was only ten and a half inches. Later on in the month two more mature plaice were captured in the same area as the previous ones. The latter were both eleven and a half inches long. These fish were brought alive to Piel. They all produced eggs which fertilised and developed quite normally. The fish were captured between Walney and Isle of Man in the area known as the "Top end of the Hole," on March 13th and 20th. According to McIntosh and Masterman* plaice appear to have very definite spawning grounds, always well offshore and at a depth of about twenty fathoms. Under artificial conditions we find it is possible to get them to spawn in much shallower water. At Port Erin the fish spawn freely in a pond with a maximum depth of ten feet. At the Bay of Nigg Hatchery, belonging to the Fishery

*British Marine Food Fishes, p. 364.

Board for Scotland, spawning takes place under similar conditions. Our small fish tanks at Piel are only about four feet deep, and we find the fish mature quite normally. During the spring of 1906 we found that some of the adult plaice, collected in Luce Bay in the autumn of 1905, matured when kept in water fourteen inches deep. The fish actually spawned in that depth of water, but the eggs were not fertilised. Very ripe female dabs collected in March, and brought alive to Piel, discharged their eggs in shallow tanks only ten inches deep. In the latter case the eggs were probably too far advanced to be retained by the fish when subjected to the greatly altered conditions of pressure. In the other case, so far as reproduction is concerned, the only apparent difference due to confinement is a slight retarding of the maturation of the eggs. We find from the tow-nettings taken in the open sea that plaice eggs were taken in Cardigan Bay on January 23rd, 1906, and off the Liverpool North-west Lightship on the 31st. The occurrence of one plaice egg in Cardigan Bay on December 15th, 1905, and the capture of a spent female plaice in the same bay on January 26th, 1906, has already been recorded by us. Fertilised eggs under artificial conditions were secured at the Bay of Nigg Hatchery on January 20th,† and at Port Erin Hatchery on February 20th, 1906.‡

The following tables give the number of eggs collected and of the fry hatched at Piel, and set free on the dates specified:—

† Twenty-fourth Annual Report Fishery Board for Scotland, part iii, p. 112.

‡ Twentieth Annual Report of the Liverpool Marine Biology Committee, p. 17.

## Plaice (*Pleuronectes platessa*, Linn.).

| Eggs Collected. | | | Fry Set Free. | | |
|---|---|---|---|---|---|
| March 14 | ... | 30,000 | 26,000 | ... | March 30 |
| ,, 16 | .. | 40,000 | 35,000 | ... | April 9 |
| ,, 19 | ... | 50,000 | 44,000 | ... | ,, ,, |
| ,, 21 | ... | 60,000 | 51,500 | ... | ,, ,, |
| ,, 24 | ... | 60,000 | 51,500 | ... | ,, ,, |
| ,, 26 | ... | 70,000 | 62,000 | ... | ,, 14 |
| ,, 28 | ... | 90,000 | 79,000 | ... | ,, ,, |
| ,, 30 | ... | 85,000 | 75,000 | ... | ,, 20 |
| April 2 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 3 | ... | 95,000 | 84,500 | ... | ,, ,, |
| ,, 5 | ... | 90,000 | 79,500 | ... | ,, 26 |
| ,, 7 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 9 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 11 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 14 | ... | 90,000 | 79,500 | ... | May 5 |
| ,, 17 | ... | 85,000 | 75,000 | ... | ,, ,, |
| ,, 20 | ... | 80,000 | 70,000 | ... | ,, ,, |
| ,, 23 | ... | 75,000 | 66,500 | ... | ,, 19 |
| ,, 26 | ... | 50,000 | 44,000 | ... | ,, ,, |
| ,, 28 | ... | 40,000 | 34,500 | ... | ,, ,, |
| ,, 30 | ... | 30,000 | 27,000 | ... | ,, ,, |
| May 3 | ... | 20,000 | 17,500 | ... | ,, ,, |
| Total Eggs | | 1,500,000 | 1,320,000 | | Total Fry |

FLOUNDER (*Pleuronectes flesus*, Linn.).

| Eggs Collected. | | | Fry Set Free. | | |
|---|---|---|---|---|---|
| March | 14 | 200,000 | 177,000 | March | 30 |
| ,, | 16 | 250,000 | 223,000 | ,, | ,, |
| ,, | 19 | 300,000 | 266,000 | ,, | ,, |
| ,, | 21 | 300,000 | 266,000 | April | 9 |
| ,, | 24 | 350,000 | 310,000 | ,, | ,, |
| ,, | 26 | 450,000 | 400,000 | ,, | ,, |
| ,, | 28 | 500,000 | 445,000 | ,, | ,, |
| ,, | 30 | 650,000 | 580,000 | ,, | 14 |
| April | 2 | 750,000 | 667,000 | ,, | ,, |
| ,, | 3 | 750,000 | 669,000 | ,, | ,, |
| ,, | 5 | 850,000 | 757,000 | ,, | 20 |
| ,, | 7 | 950,000 | 846,000 | ,, | ,, |
| ,, | 9 | 1,000,000 | 887,000 | ,, | ,, |
| ,, | 11 | 950,000 | 847,000 | ,, | ,, |
| ,, | 14 | 900,000 | 800,000 | ,, | 26 |
| ,, | 17 | 900,000 | 800,000 | ,, | ,, |
| ,, | 20 | 800,000 | 712,000 | May | 5 |
| ,, | 23 | 750,000 | 669,000 | ,, | ,, |
| ,, | 26 | 600,000 | 530,000 | ,, | ,, |
| ,, | 28 | 600,000 | 532,000 | ,, | 19 |
| ,, | 30 | 500,000 | 445,000 | ,, | ,, |
| May | 3 | 300,000 | 266,000 | ,, | ,, |
| ,, | 5 | 200,000 | 178,000 | ,, | ,, |
| ,, | 7 | 200,000 | 178,000 | ,, | ,, |
| Total Eggs | | 14,000,000 | 12,450,000 | Total Fry. | |

Total Number of Eggs ... ... ... 15,500,000

Total Number of Fry ... ... ... 13,770,000

## CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

Four classes for fishermen were held in the spring of 1906. The Education Committee of the Lancashire County Council voted a sum of money for forty-five studentships open to fishermen in the administrative County of Lancaster. The Blackpool Education Committee sent three men, Southport Education Committee two men, Liverpool Education Committee two men, and the Cheshire Education Committee four men. The studentship holders were divided into four classes, three of fifteen each and one of eleven men, as shown by the following lists:—

1st class, held March 12th to 23rd.—J. G. Constable, Askam; R. Parker, Flookburgh; Percy Baxter, Morecambe; G. Parkinson, Morecambe; T. Woodhouse, Morecambe; W. Wilson, Morecambe; R. Abram, Fleetwood; W. Ball, Fleetwood; T. Rawlinson, Fleetwood; Wm. Wright, Fleetwood; J. Abram, Banks; J. Johnstone (Bunger), Banks; J. Barrow, Blackpool; F. Parr, Blackpool; E. Salthouse, Blackpool.

2nd class, held March 26th to April 6th.—S. Mott, Bardsea; W. Benson, Flookburgh; R. Gardner, Morecambe; T. Gerrard, Morecambe; R. Ellwood, Morecambe; J. Wilson, Bolton-le-Sands; T. Smith, Overton; J. T. Bagot, Knott End; R. Ball, Fleetwood; J. Leadbetter, Fleetwood; W. Sharpe, Fleetwood; R. Gillett, Lytham; W. G. Parkinson, Lytham; P. Brookfield, Banks; J. Aughton, Banks.

3rd class, held April 23rd to May 4th.—T. Edmondson, Roosebeck; J. Gardner, Ulverston; J. Procter, Ulverston; J. Wilkinson, Baicliff; T. Westworth,

Flookburgh; W. Bird, Fleetwood; R. Wright, Fleetwood; R. Wilson, Fleetwood; J. R. Croft, Preesall; R. Swarbrick, Hambleton; W. Hadwen, Morecambe; T. Shaw, Morecambe; T. Mayor, Morecambe; R. Abram, Banks; J. Peet, Banks.

4th class, held May 7th to 18th.—J. Bird, Ulverston; R. Stephenson, Heysham; W. Baxter, Banks; J. Lloyd, Marshside; W. Ball, Southport; W. H. Hosier, Liverpool; W. Whelan, Liverpool; T. Bushell, Parkgate; T. Matthews, Parkgate; J. Murray, Liscard; W. Bedson, New Brighton.

The usual votes of thanks to the Sea Fisheries Committee and to the Education Committee were proposed and carried by the fishermen.

The classes for fishermen are now registered by the Board of Education as evening classes, and each of the above classes was inspected by Mr. M. A. Fenton, one of the Government Inspectors. Mr. Fenton's report was as follows:—

> "Demonstrations from the blackboard and abun-
> "dant individual instruction constitute the teaching
> "referred to. The men manipulate admirably, and
> "seem to apply themselves so as to receive as much
> "attention as is to be obtained in their fortnight."

A class in Nature Study for school teachers was held on two week nights and the Saturday afternoons during the period covered by the third and fourth classes for fishermen. This class was organised by the Barrow Education Committee, and was attended by eighteen teachers belonging to their schools. The teachers' class is also recognised by the Board of Education, and registered as an evening school. The following is a copy of the report on the class which was sent to the Barrow Education Committee:—

" Board of Education, South Kensington.
" Barrow-in-Furness, Piel, Marine Laboratory, Teachers'
" Classes, School No. 32,519.

" Report of H.M. Inspector for the year 1905-06, with " remarks, if any, added by the Board of Education:—

" ' This is a very useful class. The teaching is " ' efficient and thorough, and much interest is " ' evinced by the students in the study of the " ' marine forms of the syllabus.

" ' The work is conducted in a well-equipped " ' Laboratory.' "

The members of the Scientific and General Purposes Committees of the Fisheries Committee and members of various Education Committees in the County visited the laboratory, under the leadership of Mr. James Fletcher, while the fishermen's classes were being conducted.

The library has received a number of valuable additions during the year, the most important being:—

A set of fifty-eight volumes, published by the Ray Society, containing amongst others the Monographs by Alder & Hancock, Allman, McIntosh, Bowerbank, Brady, Darwin, &c.

United States Bulletins of the Fish Commission, 1884-1904. 12 vols.

British Fresh-water Fishes, Houghton. 2 vols.

Catalogue of Madreporia, vols. 1-5; presented by the British Museum.

Monograph on the Isopods of North America.

A number of books and pamphlets belonging to the late R. L. Ascroft; presented by Mrs. Ascroft.

A number of reprints of papers from the Reports on the Sea and Inland Fisheries of Ireland, 1904-1905; presented by Mr. E. W. L. Holt, Scientific Adviser.

# REPORT ON THE TOW-NETTINGS.

By Andrew Scott.

The collections of pelagic organisms taken by tow-net in various parts of the Irish Sea in 1906 number four hundred. The results from the examination of the material are given in the monthly tables (see below). Although the tables represent the organisms that were present from month to month in particular areas, it does not necessarily follow that they were always in evidence every time a collection was made. Again, the number of records for any station depends largely on the frequency of the fishing. A comparison of the tables given in last year's Report shows that Cardigan Bay had a greater variety of free swimming animals than any other area. The number of tow-nettings taken there represented more than one every week, and practically amounted to five each month. The area is a large one, and collections were made in the vicinity of New Quay and Pwllheli by the fishery officers stationed at these places. Then at intervals the fisheries steamer took tow-nettings in various parts of the territorial waters of the bay. This area, therefore, was fairly well investigated in 1906, and the results were naturally high. Another thing to be remembered is that distribution is rarely uniform. Some organisms may be extremely abundant at one spot, and yet at another, perhaps only a few miles away, are conspicuous by their absence.

During the year 1906, we derived a good deal of fresh information from the tow-nettings relating to the occurrence of various important organisms. Owing to various

circumstances, it is almost impossible to get a complete series of collections for a whole year. A continuous daily, or even weekly, sample from one particular region is apt to be interrupted through conditions of weather and other unforeseen agencies, over which there is no control. Again, a gathering taken once a day, once a week, or once a month, may yield some interesting organisms, but one would like to know what had happened in the interval, whether the organism was only a solitary example or part of a rich, widely-diffused shoal. The only area that is represented at least once every month, in 1906, is Cardigan Bay. This division was dealt with in the last Report, and further consideration of its monthly plankton is, therefore, deferred in the meantime. If the tables giving the occurrence of organisms in the areas investigated be compared, it will be noticed that during July, August and September Port Erin had a greater number of organisms than the other stations during that period. This is entirely due to the way the area was investigated and the large number of samples collected. Professor Herdman chartered the small steam yacht "Madge," and spent his summer vacation making plankton hauls in the open sea, in the vicinity of Port Erin. The region investigated lay mainly between Bradda Head and the Calf Island. The amount of work that was done can be readily understood when it is stated that on the twenty-nine working days when the "Madge" was at work seventy-three tow-nettings in all were taken. Even after the observations made from the yacht ended, other tow-nettings were taken both inside and outside Port Erin Bay by Professor Herdman and Mr. Chadwick. The result is that during the period, July 22nd to September 30th, seventy-nine collections were made. More than half that number were taken in the latter month. With such a large amount of material

to investigate, one would expect that there would be more variety in the plankton than if only one or two samples had been taken in the period. This is the case. In September no less than fifty-eight different kinds of organisms fall to be recorded. Professor Herdman, in his work on the "Madge," used five different kinds of nets, all made of fine silk bolting cloth, as follows:—

A Hensen-Petersen closing net, with 200 meshes to the inch.

A small Apstein net, with 212 meshes to the inch.

An ordinary tow-net, weighted to work below the surface, 120 meshes to the inch.

An ordinary surface net, 120 meshes to the inch, used for the first time.

An ordinary surface net, 120 meshes to the inch, that had been in use for a year.

The five nets were not often used simultaneously, as a rule only the surface and deep-water nets were worked at the same time. On measuring and examining the material collected, it was found that, although the gatherings were taken in equal periods of time in a very limited sea area, there was no strict uniformity, either in quantity or kind of organisms captured. Sometimes the surface net contained more material than the deep one, at other times there was more in the deep net than in the surface one. The old surface net appeared to fish better than the new one. The Apstein net invariably had a smaller catch than the ordinary net. When we find such differences in a small section of the Irish Sea, what must be the conditions when the whole area is fully investigated?

It is proposed, in this Report, to deal with the distribution of organisms, and to show that differences in the nature of the plankton are more frequently than

otherwise co-extensive with the area over which th operations are conducted. It is a well-known fact tha land animals and plants have a distribution which depend largely on the physical conditions of their surrounding One is apt to forget, however, that the same holds goo regarding marine life. The sea may appear limitless i extent, but, after all, there are many animals and plan in it that are just as nicely adjusted to their habitat a their relations on land, and any change that takes plac in their surroundings has some effect, one way or anothe on the inhabitants of the sea. We know far mor regarding the inhabitants of the land solely because of th comparative ease in reaching them, compared with th difficulties that lie before the marine investigator. Th worker amongst land animals and plants can now affor time to deal with variation in structure, &c., but th marine student has not, by any means, exhausted the va storehouse of the deep of all its novelties. It is onl within comparatively recent years that a wide-sprea study of marine life has been undertaken. Th co-operation of the Governments of various countries an Sea-Fisheries Authorities, along with the efforts put fort by independent naturalists, has done much to stimulat marine research. The result is, we know a great dea more regarding the distribution of certain classes o pelagic and semi-pelagic organisms now than we did a fe years ago. Every scientific expedition throws fresh ligh on the subject. There are still quite a number o organisms whose present distribution is very limited, bu whether they will prove on further investigation to be s local is doubtful. Many new forms of Copepoda wer brought to light by the investigations conducted on th "Challenger" over thirty years ago. Some of the were found in tropical seas, and might have been looke

upon still as true warm-water species, but quite lately one or two of these species have been detected off the Coast of Norway and in the deep cold area of the Faröe Channel. Pelagic forms of Copepoda are probably more widely distributed than might be expected. When one, however, finds such a typical littoral form as *Phyllothalestris mysis* (first described by Claus, from the Mediterranean) having its distribution afterwards extended to Norway and Ceylon, or a more inert species like *Laophontodes bicornis* (described from specimens found off the Isle of Man) extending to Cape Verde Islands, there can be little surprise at the occurrence of pelagic forms in unexpected places. In the ordinary course of events, true littoral Copepods are rarely taken in tow-nets, unless these are worked near the bottom. Other means have to be employed for their capture, such as dredging and washing debris from larger invertebrata. It is obvious that it cannot be accurate to state that littoral forms of any kind are absent if the proper methods for collecting them are omitted. A handful of weed washed in weak spirit often brings to light a surprising number of organisms, such as Foraminifera, Ostracoda and littoral Copepoda, that would not be obtained any other way. Two instances of that kind have come under my own notice. One was the washings from a handful of algæ, hurriedly gathered on the shore of the Island of Sokotra, which contained a number of interesting Amphipoda and Isopoda. The other was a small quantity of calcareous and other algæ collected on the dead coral reef flats and madrepora reefs in the Conflict atoll, off the Coast of British New Guinea. When carefully washed and examined, these debris yielded a large number of littoral Copepoda and Ostracoda. Some of the littoral Copepoda from this distant island appear to be

identical with forms we occasionally find in the Irish Sea.

Quite a number of samples of surface plankton have been taken in limited areas of the Irish Sea *on the same day* by the steamer, the Fishery officers, Professor Herdman, and Mr. Chadwick in the course of this year. The results are given on the following pages. Except where otherwise mentioned, the collections were secured with an ordinary open tow-net worked close to the surface.

On January 3rd, a collection was taken off Blackpool and another near the Liverpool Bar Lightship. These places are about forty miles apart. The following are the organisms found* in each :—

| | Blackpool. | | Liverpool Bar. |
|---|---|---|---|
| Rhizosolenia semispina ..... | c. | ... | r. |
| Rhizosolenia shrubsolei ..... | r. | ... | r. |
| Ceratium tripos ..... | fr. | ... | — |
| Ceratium fusus ..... | fr. | ... | r. |
| Noctiluca ..... | fr. | ... | — |
| Sagitta ..... | ab. | ... | c. |
| Copepoda ..... | ab. | ... | r. |
| Temora ..... | c. | ... | — |
| Acartia clausi..... | c. | ... | r. |
| Paracalanus ..... | c. | ... | r. |
| Oithona similis ..... | c. | ... | — |
| Oithona nana ..... | r. | ... | — |
| Centropages hamatus ..... | r. | ... | — |
| Pseudocalanus ..... | r. | ... | r. |

The difference here is very marked, thirteen organisms occurring at Blackpool and only seven at Liverpool Bar. Three out of the seven species of Copepods are absent at the latter place. Samples taken more in the open sea on the following day near the Liverpool North-west Lightship and in Red Wharf Bay—places about forty-five miles apart—gave the following result :—

* ab. abundant ; c. common ; fr. frequent ; r. rare ; v.ab. very abundant.

| | N.W. Light Ship. | | Red Wharf Bay. |
|---|---|---|---|
| Coscinodiscus concinnus | fr. | ... | — |
| Biddulphia mobiliensis | r. | ... | — |
| Ceratium tripos | r. | ... | — |
| Noctiluca | r. | ... | fr. |
| Pleurobrachia | 1 | ... | — |
| Autolytus | 1 | ... | fr. |
| Sagitta | r. | ... | ab. |
| Tomopteris | — | ... | r. |
| Podon | r. | ... | — |
| Hyperia galba | 2 | ... | — |
| Parathemisto oblivia | 2 | ... | — |
| Copepoda | ab. | ... | c. |
| Calanus | r. | ... | r. |
| Temora | fr. | ... | fr. |
| Centropages hamatus | r. | ... | — |
| Paracalanus | — | ... | r. |
| Acartia clausi | v. ab. | ... | fr. |
| Oithona similis | fr. | ... | — |
| Oikopleura | r. | ... | — |

The differences between these two collections are quite as marked as in the previous examples. There was, evidently, a more abundant supply of life out in the open sea than near the land, and it will be noticed that diatoms were absent from territorial waters. There was a great difference in the amount of Copepoda in the two areas. *Acartia clausi* was present in immense numbers offshore, while in Red Wharf Bay the number of this particular species was considerably reduced.

On January 22nd one tow-netting was taken in Port Erin Bay, on the following day two were taken in Cardigan Bay by the steamer, and one by Capt. Jones in Carnarvon Bay. The tow-netting from Port Erin is not strictly comparable with the others, but is given to show the difference between the plankton from the Central area on one day, and that from close inshore in the Southern area on the next day.

| | Port Erin. | Near Patches Buoy. | Off Llanon. | Carnarvon Bay. |
|---|---|---|---|---|
| Biddulphia | ab. | r. | — | — |
| Chætoceros | ab. | — | — | — |
| Coscinodiscus | ab. | — | — | — |
| Rhizosolenia | r. | — | — | — |
| Acanthometra | r. | — | — | — |
| Ceratium tripos | fr. | fr. | — | — |
| Ceratium fusus | fr. | — | — | — |
| Sagitta | fr. | fr. | — | r. |
| Tomopteris | fr. | fr. | — | — |
| Autolytus | — | r. | — | r. |
| Mitraria | r. | fr. | — | — |
| Copepoda | c. | c. | — | ab. |
| Calanus | r. | — | — | — |
| Pseudocalanus | fr. | fr. | — | ab. |
| Paracalanus | fr. | fr. | — | c. |
| Temora | — | fr. | — | c. |
| Anomalocera | — | — | — | — |
| Centropages hamatus | — | r. | — | — |
| Acartia | c. | c. | — | — |
| Oithona | fr. | — | — | — |
| Euterpina | r. | — | — | — |
| Oikopleura | fr. | — | — | — |
| Plaice eggs | — | 4 | 4 | — |
| Post-larval Herring | — | ab. | — | — |

The plankton of Port Erin was very rich in Diatoms, and most of the other organisms mentioned were well represented. The inshore waters of the Southern area possessed quite a different plankton on the following day. Diatoms, with the exception of a few *Biddulphia* taken near the Patches Buoy, were absent, both in Cardigan and Carnarvon Bays. The Copepoda at the Patches Buoy were about as numerous as at Port Erin, but there was a slight difference in the species at the two places. Carnarvon Bay, again, was distinct from any of the other three, and had a very rich supply of Copepoda, but little else. The collection taken off Llanon was rather remarkable, as it only contained four plaice eggs.

Tow-nettings taken in any area at intervals frequently show great changes in the pelagic organisms. This is illustrated in the two tables now given, which show the result from a gathering near the Liverpool N.W. Lightship and one in Red Wharf Bay, on January 31st.

| | N.W. Light Ship. | | Red Wharf Bay. |
|---|---|---|---|
| Biddulphia | — | ... | fr. |
| Pleurobrachia | r. | ... | — |
| Sagitta | c. | ... | ab. |
| Autolytus | l | ... | — |
| Mitraria | r. | ... | — |
| Crab zoea | r. | ... | — |
| Copepoda | c. | ... | v. ab. |
| Calanus | fr. | ... | c. |
| Pseudocalanus | fr. | ... | c. |
| Paracalanus | fr. | ... | c. |
| Temora | fr. | ... | c. |
| Acartia clausi | c. | ... | c. |
| Oithona similis | — | ... | c. |
| Plaice eggs | l | ... | — |

When these results are compared with those given for January 4th, it will be seen that Diatoms and Copepods were then fairly abundant in the open sea off the Lightship, but in Red Wharf Bay the former were absent altogether and Copepoda much scarcer. In the above examples a complete reversal is shown to have taken place in the course of twenty-seven days. Diatoms are absent from the open sea collection, and Copepoda much reduced in quantity. On the other hand, Diatoms have come into Red Wharf Bay, and Copepoda become very abundant. Such marked changes are often found, not only after intervals of time, but frequently in a very limited area, on the same day. On February 1st, four tow-nettings were taken along the coast of North Wales, between Red Wharf Bay and Rhyl, which show that

although organisms may be widely distributed the relative abundance may change. The distance between Red Wharf Bay and Rhyl is about fifteen miles, and the following tables show the distribution:—

| | Red Wharf Bay. | Off Puffin Island. | Conway Bay. | Off Rhyl. |
|---|---|---|---|---|
| Biddulphia | r. | — | — | r. |
| Coscinodiscus | r. | fr. | fr. | r. |
| Ceratium tripos | r. | — | — | r. |
| Pleurobrachia | — | r. | r. | r. |
| Sagitta | r. | v. ab. | v. ab. | r. |
| Autolytus | r. | — | — | r. |
| "Mitraria" | r. | — | — | — |
| Copepoda | c. | c. | c. | c. |
| Calanus | — | — | r. | — |
| Pseudocalanus | fr. | fr. | fr. | fr. |
| Paracalanus | fr. | fr. | fr. | fr. |
| Temora | fr. | fr. | fr. | fr. |
| Acartia clausi | fr. | fr. | fr. | fr. |
| Oithona similis | r. | r. | r. | r. |
| Euterpina | r. | r. | r. | r. |
| Plaice eggs | — | 1 | — | — |

The collections taken in Red Wharf Bay and off Rhyl show that the plankton was practically the same at the two places. The intermediate stations, however, show important differences. At the extreme ends of this area Diatoms were rare, and only two genera were represented; *Sagitta* was also scarce. The plankton in the vicinity of Puffin Island and in Conway Bay contained one of the two genera of Diatoms only, but the increase in the number of specimens was quite conspicuous. *Sagitta*, on the other hand, constituted the bulk of the intermediate gatherings, and it is probable that a shoal had been passed through during these observations. This shoal appeared to be quite limited in width and depth, as

only a few specimens were captured by the bottom tow-nets. It will be noticed, too, that only one plaice egg was taken along this fifteen mile line.

The conditions prevailing in the open sea, off the North-East end of the Isle of Man, about the middle of February, are shown by the following three collections, taken in the vicinity of Bahama Bank on February 20th:—

| | (1) | (2) | (3) |
|---|---|---|---|
| Sagitta | ab. | c. | ab. |
| Tomopteris | — | — | r. |
| Autolytus | — | r. | r. |
| Copepoda | c. | c. | c. |
| Calanus | fr. | fr. | ft. |
| Pseudocalanus | ab. | ab. | ab. |
| Paracalanus | fr. | fr. | fr. |
| Centropages | r. | r. | r. |
| Acartia | r. | r. | r. |
| Crab zoea | — | — | r. |
| Eurydice | — | — | l |
| Hyperia | — | — | l |
| Mysis | — | — | l |
| Nyctiphanes | — | — | l |
| Plaice eggs | ab. | ab. | fr. |
| Flounder eggs | r. | r. | r. |

The differences in these are very slight, and show that the distribution was fairly uniform. The presence of the higher crustacea in the third haul, the reduction in quantity of *Sagitta* in the second haul, and the decrease in plaice eggs in the third haul are the only important features.

On February 21st one tow-netting was taken in Red Wharf Bay and one in the open sea about twelve miles North-East from the bay. Considerable change in the collections is shown in the following list of organisms:—

| | Red Wharf Bay. | | 12 Miles N. |
|---|---|---|---|
| Biddulphia | c. | ... | ab. |
| Coscinodiscus | fr. | ... | ab. |
| Ceratium fusus | — | ... | r. |
| Sagitta | — | ... | 6 |
| Autolytus | — | ... | 2 |
| Copepoda | r. | ... | r. |
| Calanus | r. | ... | r. |
| Paracalanus | r. | ... | r. |
| Acartia | r. | ... | r. |
| Oithona | r. | ... | r. |
| Plaice eggs | — | ... | r. |
| Cod eggs | r. | ... | — |
| Haddock eggs | r. | ... | — |
| Bib eggs | — | ... | r. |
| Rockling eggs | r. | ... | — |

The open sea contained more Diatoms than territorial waters. A few *Sagitta* and *Autolytus* w present in the open sea, but entirely absent inshore. T eggs of plaice and bib were taken in the open sea on and those of cod, haddock and rockling inshore.

Two collections taken six miles apart in the ar sixteen miles W.N.W. of Piel, gave practically eq results on March 13th, but the constituents of plankton were very different from what prevailed in open sea off Red Wharf Bay two weeks before.

| | (1) | | (2) |
|---|---|---|---|
| Sagitta | r. | ... | r. |
| Autolytus | — | ... | r. |
| Copepoda | r. | ... | r. |
| Acartia | r. | ... | r. |
| Paracalanus | r. | ... | r. |
| Plaice eggs | ab. | ... | ab. |
| Flounder eggs | ab. | ... | ab. |
| Dab eggs | ab. | ... | ab. |
| Cod eggs | ab. | ... | ab. |

On March 20th tow-nettings were taken in territorial waters off New Quay Head, in Carnarvon Bay, near Duddon Buoy, and in the open sea fifteen miles West from the entrance to the Duddon. These throw light on the conditions in the territorial waters at the extreme limits of the district, and also enable a comparison to be made between the open sea and inshore waters at the North end of the area.

| | Off New Quay. | Carnarvon Bay. | Duddon Buoy. | 15 Miles W. from Duddon. |
|---|---|---|---|---|
| Coscinodiscus | — | r. | — | — |
| Biddulphia | — | r. | — | — |
| Sagitta | — | r | r. | r. |
| Autolytus | r. | r. | — | — |
| Crab zoea | c. | — | r. | r. |
| Nauplii of barnacles | c. | v. ab. | — | — |
| Ostracod stage of barnacles... | — | r. | — | — |
| Copepoda | r. | r. | r. | r. |
| Calanus | — | — | r. | r. |
| Paracalanus | — | — | r. | r. |
| Temora | — | r. | r. | r. |
| Acartia | r. | r. | r. | r. |
| Plaice eggs | r. | — | r. | r. |
| Flounder eggs | — | — | r. | r. |
| Cod eggs | — | — | r. | r. |
| Whiting eggs | ab. | r. | r. | r. |
| Bib | ab. | — | r. | r. |
| Rockling | ab. | r. | r. | r. |

Diatoms and barnacle larvæ were present in Carnarvon Bay only. Copepoda were very scarce at all the stations, but a noticeable difference in variety of species is obvious at the northern area. The eggs of whiting and rockling occurred in all the four collections, but were more numerous off New Quay than in the others. Plaice and bib were present at the North and South extremities, cod and flounder at the North end only. The open sea plankton was the same as that found inshore.

Two collections were taken near Duddon Buoy on March 31st, within three miles of each other, and although they gave similar results so far as variety of the constituents go, showed great difference in relative abundance of Diatoms and *Sagitta*.

| | Duddon Buoy. | | 3 Miles N.W. from the Buoy. |
|---|---|---|---|
| Biddulphia | v. ab. | ... | c. |
| Chætoceros | r. | ... | r. |
| Coscinodiscus | v. ab. | ... | c. |
| Rhizosolenia | r. | ... | r. |
| Ceratium tripos | fr. | ... | r. |
| Ceratium fusus | fr. | ... | r. |
| Alcyonium eggs | r. | ... | r. |
| Sagitta | r. | ... | v. ab. |
| Eurydice | r. | ... | r. |
| Copepoda | c. | ... | c. |
| Pseudocalanus | fr. | ... | fr. |
| Paracalanus | fr. | ... | fr. |
| Temora | r. | ... | r. |
| Acartia | fr. | ... | fr. |
| Plaice eggs | r. | ... | — |
| Bib eggs | r. | ... | r. |

It will be seen that there was a greater abundance of Diatoms, chiefly *Biddulphia* and *Coscinodiscus*, near the buoy than further off, and also that *Sagitta* were more plentiful three miles away from the buoy than close to it. A comparison of these two collections with the one taken close to Duddon Buoy on March 20th, shows a very marked change. Eleven days before these later ones were secured no Diatoms at all were present, and yet, in the course of a short period, they have made their appearance in large numbers.

On April 24th three tow-nettings were taken near the Morecambe Bay Lightship, within an area of about six miles. The results are almost identical, and it is evident

that the constituents were fairly uniformly diffused at this place at the time the samples were taken.

| | (1) | (2) | (3) |
|---|---|---|---|
| Biddulphia | ab. | ab. | ab. |
| Coscinodiscus | ab. | ab. | ab. |
| Rhizosolenia | ab. | ab. | ab. |
| Ceratium tripos | c. | c. | c. |
| Ceratium fusus | c. | c. | c. |
| Alcyonium eggs | r. | r. | r. |
| Sagitta | — | — | r. |
| Autolytus | r. | r. | r. |
| Crab zoea | r. | r. | c. |
| Copepoda | r. | r. | c. |
| Temora | r. | r. | c. |
| Paracalanus | r. | r. | r. |
| Acartia | r. | r. | c. |
| Ascidian eggs | c. | c. | c. |
| Oikopleura | r. | r. | r. |
| Dab eggs | v.ab. | v.ab. | v.ab. |
| Haddock eggs | v.ab. | v.ab. | v.ab. |
| Whiting eggs | v.ab. | v.ab. | v.ab. |
| Bib eggs | v.ab. | v.ab. | v.ab. |

Collections taken at the North end of Cardigan Bay, on April 27th, show considerable variation in the constituents of the plankton, as will be seen from the following tables:—

| | Tremadoc Bay | Off Llanbedrog. | Off Kilan Head. |
|---|---|---|---|
| Biddulphia | — | — | r. |
| Chætoceros | r. | — | — |
| Coscinodiscus | ab. | — | r. |
| Rhizosolenia | r. | — | — |
| Alcyonium eggs | r. | — | — |
| Sagitta | r. | r. | r. |
| Crab zoea | — | r. | r. |
| Nauplii of barnacles | — | c. | c. |
| Ostracod stage of barnacles | c. | c. | c. |
| Copepoda | c. | c. | r. |
| Pseudocalanus | — | fr. | — |
| Temora | fr. | fr. | — |
| Centropages | fr. | fr. | — |
| Acartia | fr. | fr. | r. |
| Oithona | r. | c. | — |
| Brill eggs | — | — | r. |
| Haddock eggs | — | — | r. |
| Pollack eggs | — | r. | — |
| Sprat eggs | r. | r. | r. |
| Rockling eggs | — | r. | — |
| Spotted Dragonet eggs | — | r. | — |

Diatoms, especially *Coscinodiscus*, were plentiful i Tremadoc Bay, absent altogether off Llanbedrog, and ver scarce off Kilan Head. Copepoda, though common i Tremadoc Bay and off Llanbedrog, were nearly absent a Kilan Head. At the latter place only one species *Acartia*, was detected. Fish eggs were very unevenl distributed, and out of a total of six different kind present in the northern portion of Cardigan Bay onl one was represented in Tremadoc Bay.

On May 7th, three collections were again taken nea Morecambe Bay Lightship. The first were taken close t the ship, the second five miles West, and the third eigh miles West from it. The plankton was identical in thes samples.

| | (1) | | (2) | | (3) |
|---|---|---|---|---|---|
| Biddulphia | r. | ... | r. | ... | r. |
| Coscinodiscus | r. | ... | r. | ... | r. |
| Rhizosolenia | v.ab. | ... | v.ab. | ... | v.ab. |
| Ceratium fusus | c. | ... | c. | ... | c. |
| Alcyonium eggs | r. | ... | r. | ... | r. |
| Pleurobrachia | r. | ... | r. | ... | r. |
| Sagitta | r. | ... | r. | ... | r. |
| Ostracod stage of barnacles | c. | ... | c. | ... | c. |
| Copepoda | c. | ... | c. | ... | c. |
| Pseudocalanus | fr. | ... | fr. | ... | fr. |
| Temora | fr. | ... | fr. | ... | fr. |
| Centropages | fr. | ... | fr. | ... | fr. |
| Acartia | fr. | ... | fr. | ... | fr. |
| Sprat eggs | r. | ... | r. | ... | r. |
| Gurnard eggs | — | ... | r. | ... | r. |

Although these collections are all practically th same, they show some differences from the former sampl taken on April 24th. On the first occasion three gene of Diatoms were present, but all were equally abundan Thirteen days later two of the genera were exceedingl scarce, while the third, *Rhizosolenia*, had increased i quantity. The complete change in fish eggs is to b

expected. Those noted on the earlier date had probably been hatched, or widely scattered by winds and currents before the second visit. Copepoda had become more plentiful, and the free swimming ostracod stage of barnacles made their appearance amongst the pelagic organisms taken on May 7th.

On May 15th tow-nettings were taken off Blackpool, at the entrances to the Ribble and Mersey, in Carnarvon Bay and off New Quay Head. The differences between the plankton collected off the Lancashire coast and that from the Welsh areas is very marked.

| | Off Blackpool. | Ribble entrance. | Mersey entrance. | Carnarvon Bay. | Off New Quay. |
|---|---|---|---|---|---|
| Biddulphia | r. | r. | r. | v.ab. | r. |
| Coscinodiscus | r. | r. | r. | v.ab. | r. |
| Rhizosolenia | ab. | ab. | ab. | — | — |
| Ceratium tripos | r. | r. | r. | — | — |
| Ceratium fusus | r. | — | r. | — | — |
| Ceratium furca | r. | — | — | — | — |
| Noctiluca | r. | — | r. | — | — |
| Pleurobrachia | c. | — | c. | — | — |
| Sagitta | r. | r. | r. | — | r. |
| " Mitraria " | r. | — | r. | — | — |
| Crab zoea | r. | r. | r. | — | — |
| Ostracod stage of barnacles | — | — | — | c. | — |
| Copepoda | r. | r. | r. | c. | v.ab. |
| Paracalanus | r. | r. | r. | — | c. |
| Temora | — | — | — | c. | c. |
| Centropages | — | — | — | c. | c. |
| Anomalocera | — | r. | — | — | fr. |
| Isias | — | — | — | — | r. |
| Acartia clausi | r. | r. | r. | — | c. |
| Acartia discaudata | r. | — | r. | — | — |
| Evadne | — | r. | r. | — | — |
| Oikopleura | r. | r. | c. | — | — |
| Brill eggs | — | — | — | — | r. |
| Rockling eggs | — | — | — | — | r. |

Three genera of Diatoms were represented on the Lancashire coast, but only one of these was plentiful, the

other two were rare. In Carnarvon Bay it was found that the form so abundant between the Mersey entrance and Blackpool was quite absent, but the other two were present in immense numbers. Off New Quay the abundant member of the northern waters was also absent, and the other two rare. The Copepoda were very unequally distributed, large numbers were found off New Quay, a fair quantity in Carnarvon Bay, and only a very few in the North District. Fish eggs were only observed in the collection from New Quay. The distinction between the constituents of the plankton on the Welsh and Lancashire coasts is very marked.

The following two results show the conditions existing close to land and in the open sea. On May 22nd one collection was taken off the entrance to the Ribble and one close to the Liverpool North-West Lightship. The latter is about seventeen miles S.W. from the former.

| | Ribble Entrance. | | Liverpool N.W. Lightship. |
|---|---|---|---|
| Coscinodiscus | r. | ... | r. |
| Rhizosolenia | r. | ... | r. |
| Ceratium tripos | r. | ... | r. |
| Ceratium fusus | r. | ... | r. |
| Pleurobrachia | r. | ... | — |
| "Mitraria" | r. | ... | r. |
| Sagitta | r. | ... | r. |
| Crab zoea | — | ... | r. |
| Crab megalopa | r. | ... | — |
| Podon | — | ... | r. |
| Evadne | r. | ... | — |
| Copepoda | r. | ... | c. |
| Paracalanus | r. | ... | r. |
| Temora | r. | ... | c. |
| Centropages | — | ... | c. |
| Anomalocera | r. | ... | — |
| Acartia | r. | ... | c. |
| Oikopleura | r. | ... | r. |
| Brill eggs | — | ... | r. |
| Rockling eggs | — | ... | r. |

The most noticeable difference between the two stations is the relative abundance of the Copepoda; these were more numerous in the open sea than close inshore.

The other organisms, with the exception of the fish eggs, appeared to be fairly uniform in their distribution on that date. A comparison of the plankton at the Ribble entrance on the above date with that of seven days previously shows a great change in the quantity of Diatoms on the two dates. On the first date three genera were represented, one of which was present in large numbers on the second visit, one of the forms had disappeared, and the prevalent genus had decreased so very much in quantity that only a few specimens were detected.

On May 24th two tow-nettings were taken in Cardigan Bay, one near the Patches Buoy and the other off New Quay Head, about fourteen miles S.W. from the former. A third collection was made off Dinas Head, about twenty-three miles in a westerly direction from New Quay Head. These three were all from inside the territorial limit, and give an idea of the conditions of the plankton along that portion of the Welsh coast.

| | Patches Buoy. | New Quay Head. | Dinas Head. |
|---|---|---|---|
| Pleurobrachia | c. | — | r. |
| Sarsia tubulosa | — | — | c. |
| Sagitta | r. | c. | c. |
| Autolytus | r. | — | r. |
| "Mitraria" | r. | r. | — |
| Podon | — | r. | — |
| Crab zoea | — | r. | c. |
| Megalopa | — | — | c. |
| Copepoda | ab. | ab. | c. |
| Calanus | — | — | r. |
| Pseudocalanus | c. | c. | fr. |
| Paracalanus | c. | c. | fr. |
| Temora | c. | c. | fr. |
| Centropages | c. | c. | fr. |
| Oikopleura | — | r.¶ | — |
| Brill eggs | r. | r.¶ | — |
| Turbot eggs | — | r. | — |
| Gurnard eggs | r. | — | r. |
| Sprat eggs | — | r. | — |
| Rockling eggs | — | — | r. |

The distribution of the organisms in this area was evidently far from uniform. The Copepoda in the first

two were practically identical, and they were more abundant there than off Dinas Head. On the other hand, Crab Zoea and Megalopa, though tolerably common off Dinas Head, were quite absent at the Patches Buoy. Four out of the five kinds of fish eggs occurred off New Quay, and two only at the other places.

Three weeks later, June 14th, the same area was again traversed, and the following are the results then obtained:—

| | Patches Buoy. | New Quay Head. | Dinas Head. |
|---|---|---|---|
| Pleurobrachia | — | r. | c. |
| Sagitta | r. | — | c. |
| Autolytus | r. | r. | — |
| "Mitraria" | r. | — | — |
| Crab zoea | r. | c. | c. |
| Crab megalopa | — | r. | r. |
| Copepoda | ab. | ab. | r. |
| Calanus | — | — | r. |
| Pseudocalanus | r. | — | — |
| Paracalanus | c. | c. | — |
| Temora | c. | — | r. |
| Centropages | r. | r. | r. |
| Acartia | ab. | ab. | — |
| Oikopleura | — | — | c. |
| Mackerel eggs | r. | ab. | — |
| Rockling eggs | c. | c. | — |
| Weever eggs | — | r. | — |
| Common Dragonet eggs | — | r. | — |

There is very little difference in the plankton of the two periods, excepting a natural change in the kind of fish eggs. Copepoda continued to be abundant at the South end of Cardigan Bay, and scarce off Dinas Head. *Acartia*, which was not seen in the Cardigan Bay collections on May 24th, was extremely plentiful on the second occasion. Crab Zoea were more common off New Quay Head, and had extended to the region of the

Patches Buoy on the second visit. Off New Quay Head the sea was richly populated with the eggs of mackerel.

On July 12th tow-nettings were taken off Puffin Island, in Red Wharf Bay, and off Kilan Head at the North end of Cardigan Bay. The results showed extreme differences:—

| | Off Puffin Island. | Red Wharf Bay. | Kilan Head. |
|---|---|---|---|
| Noctiluca | v.ab. | v.ab. | — |
| Sagitta | r. | — | — |
| Crab zoea | r. | — | c. |
| Crab megalopa | r. | — | c. |
| Evadne | — | — | v.ab. |
| Copepoda | v.r. | — | v.ab. |
| Calanus | v.r. | — | c. |
| Temora | v.r. | — | — |
| Centropages | v.r. | — | c. |
| Isias | — | — | fr. |
| Anomalocera | — | — | fr. |
| Acartia | v.r. | — | v.ab. |
| Brill eggs | — | — | r. |
| Sprat eggs | — | — | r. |
| Weever eggs | — | — | r. |
| Rockling eggs | — | — | r. |

The plankton in Red Wharf Bay consisted of *Noctiluca* only. Off Puffin, the chief constituent was again *Noctiluca*. The other organisms mentioned were represented by a few individuals. The collection taken off Kilan Head gave quite different results. The plankton there, at that time, was practically composed of *Evadne* and *Acartia* in great abundance. *Calanus*, *Centropages* and larvæ of crabs were tolerably common.

Collections off Blackpool and at the entrance to the Ribble were taken on July 18th. These stations are only about six miles apart, yet the plankton was very distinct in each place.

| | Off Blackpool. | | Entrance to Ribble. |
|---|---|---|---|
| Ceratium tripos | c. | ... | r. |
| Noctiluca | c. | ... | r. |
| Sagitta | — | ... | r. |
| Crab zoea | c. | ... | v.ab. |
| Crab megalopa | r. | ... | v.ab. |
| Copepoda | v.r. | ... | r. |
| Centropages | v.r. | ... | r. |
| Temora | v.r. | ... | r. |
| Anomalocera | v.r. | ... | r. |
| Acartia | — | ... | r. |
| Oikopleura | — | ... | r. |

*Noctiluca*, though tolerably common off Blackpool, was almost absent a few miles away. On the other hand, the collection taken at the entrance to the Ribble consisted of little else than Zoea and Megalopa of crabs. Off Blackpool the former was fairly numerous, and the latter very scarce.

The North Wales area was traversed again on August 10th, and tow-nettings were taken in Llandudno Bay, off Puffin Island and in Red Wharf Bay. These collections differed from each other, and also showed great changes when compared with the plankton found four weeks previously.

| | Llandudno Bay. | | Off Puffin Island. | | Red Wharf Bay. |
|---|---|---|---|---|---|
| Rhizosolenia | — | ... | — | ... | r. |
| Ceratium tripos | — | ... | r. | ... | r. |
| Noctiluca | v.ab. | ... | — | ... | v.ab. |
| Pleurobrachia | — | ... | — | ... | r. |
| Sagitta | r. | ... | — | ... | — |
| Crab zoea | — | ... | c. | ... | — |
| Crab megalopa | r. | ... | — | ... | r. |
| Copepoda | — | ... | r. | ... | r. |
| Temora | — | ... | r. | ... | r. |
| Centropages | — | ... | r. | ... | r. |
| Acartia | — | ... | r. | ... | r. |
| Oikopleura | — | ... | — | ... | r. |
| Weever eggs | — | ... | — | ... | r. |

The plankton in Llandudno Bay was practically composed of *Noctiluca*. In Red Wharf Bay similar conditions prevailed, but the *Noctiluca* was mixed with a few other organisms. It will be noted, too, that *Rhizosolenia* was apparently just making its appearance.

The intermediate plankton in the vicinity of Puffin Island was quite distinct from that found at the ends of the area. There was no *Noctiluca* at all, but Crab Zoea were tolerably common. Comparing these results with the condition existing a month before, we find that the sea close to Puffin Island was then swarming with *Noctiluca*, and that Crab Zoeæ were very scarce. In Red Wharf Bay we had only pure *Noctiluca* at the beginning of August, now other organisms are making their appearance.

After the lapse of another month the area was partly investigated again, and at the same time a sample of the plankton in the Central area was secured. Collections were taken on September 7th in Llandudno, Conway and Red Wharf Bays, and in the vicinity of Port Erin. The following are results:—

| | Llandudno Bay. | Conway Bay. | Red Wharf Bay. | Port Erin. |
|---|---|---|---|---|
| Biddulphia | — | — | r. | — |
| Chætoceros | — | — | r. | — |
| Rhizosolenia | — | — | ab. | — |
| Ceratium tripos | c. | c. | c. | c. |
| Ceratium fusus | — | — | r. | — |
| Noctiluca | c. | c. | c. | — |
| Pleurobrachia | c. | — | c. | — |
| Sagitta | c. | c. | c. | c. |
| Autolytus | — | — | — | r. |
| Tomopteris | — | — | r. | — |
| Crab zoea | — | c. | — | c. |
| Crab megalopa | — | c. | c. | — |
| Podon | — | — | — | c. |
| Evadne | — | — | — | c. |
| Copepoda | c. | c. | c. | ab. |
| Calanus | — | — | — | c. |
| Pseudocalanus | — | — | — | c. |
| Paracalanus | fr. | fr. | fr. | c. |
| Anomalocera | — | — | — | c. |
| Temora | fr. | — | — | c. |
| Centropages | fr. | fr. | fr. | r. |
| Isias | — | — | — | r. |
| Acartia | c. | c. | c. | c. |
| Oithona | — | — | — | c. |
| Eurydice | — | — | r. | — |
| Parathemisto | r. | — | r. | — |
| Hyperia | r. | — | — | — |
| Oikopleura | — | — | r. | — |

*Noctiluca* was less abundant, but the Copepoda ha become more numerous, since the visit on August 10t Diatoms appeared to be increasing, and *Rhizosolenia* wa extremely plentiful compared with the results obtained month before in Red Wharf Bay. The sea near Po Erin had a rich supply of Copepods, but no Diatoms we present.

On September 14th one tow-netting was taken i Red Wharf Bay, one at the entrance to the Mersey ar one in the vicinity of Port Erin. The results show son differences between the two coastal areas, and a very gre distinction between the plankton of the coast and that the Central area.

| | Red Wharf Bay. | Entrance to Mersey. | Port Eri |
|---|---|---|---|
| Rhizosolenia | r. | — | — |
| Ceratium tripos | c. | c. | c. |
| Ceratium fusus | r. | r. | — |
| Noctiluca | c. | c. | — |
| Pleurobrachia | c. | — | — |
| Sagitta | c. | r. | r. |
| Autolytus | — | — | r. |
| Mitraria | r. | — | — |
| Crab zoea | — | r. | r. |
| Crab megalopa | c. | r. | — |
| Evadne | — | — | c. |
| Podon | — | — | c. |
| Copepoda | r. | r. | c. |
| Calanus | — | — | fr. |
| Pseudocalanus | — | — | fr. |
| Paracalanus | — | — | fr. |
| Temora | r. | r. | fr. |
| Centropages | r | r. | fr. |
| Anomalocera | — | — | fr. |
| Acartia | r. | r. | fr. |
| Oithona | — | — | fr. |
| Oikopleura | — | r. | fr. |

Considerable change had evidently taken place in Red Wharf Bay in the course of seven days. A week previous to this sample being taken the bay was full of *Rhizosolenia*, with representatives of *Coscinodiscus* and *Biddulphia*. Now we see that the two latter have gone, and the first has become very scarce. Copepoda continued to be very scarce along the coast, but were tolerably common in the Central area.

A partial investigation of the North Wales area was again made on October 25th. One collection was taken off Puffin Island and one in Llandudno Bay. A tow-netting was taken in the vicinity of Port Erin on the same day, so that it is possible to compare the coastal plankton with that in the Central area.

| | Off Puffin Island. | | Llandudno Bay. | | Port Erin. |
|---|---|---|---|---|---|
| Biddulphia | — | ... | — | ... | r. |
| Chætoceros | c. | ... | c. | ... | ab. |
| Coscinodiscus | ab. | ... | v.ab. | ... | c. |
| Rhizosolenia | c. | ... | c. | ... | — |
| Ceratium tripos | c. | ... | c. | ... | r. |
| Ceratium furca | c. | ... | c. | ... | — |
| Ceratium fusus | c. | ... | c. | ... | r. |
| Pleurobrachia | r. | ... | r. | ... | r. |
| Sagitta | v.ab. | ... | c. | ... | c. |
| Copepoda | v.ab. | ... | c. | ... | ab. |
| Calanus | — | ... | — | ... | r. |
| Pseudocalanus | — | ... | — | ... | fr. |
| Paracalanus | c. | ... | fr. | ... | fr. |
| Temora | c. | ... | fr. | ... | fr. |
| Centropages | c. | ... | fr. | ... | — |
| Acartia | c. | ... | fr. | ... | c. |
| Oithona | c. | ... | fr. | ... | fr. |
| Oikopleura | — | ... | — | ... | fr. |

The above tables show that Diatoms had become very numerous in the coastal waters of North Wales, and also that, although they were not uniformly distributed, the

visitation had extended to the Isle of Man. The most abundant form along the North Wales coast was *Coscinodiscus*, while *Chætoceros* was the most conspicuous at Port Erin. *Sagitta* was extremely plentiful off Puffin Island, and tolerably common in Llandudno Bay and at Port Erin. Copepoda had increased in quantity in the coastal area in the course of six weeks, and were also abundant at Port Erin.

On November 1st one collection was made at the entrance to the Ribble and another in Red Wharf Bay. These show that Diatoms were widely distributed in the territorial area.

| | Entrance to Ribble. | | Red Wharf Bay. |
|---|---|---|---|
| Coscinodiscus | c. | ... | c. |
| Rhizosolenia | r. | ... | r. |
| Ceratium tripos | c. | ... | c. |
| Ceratium fusus | c. | ... | — |
| Noctiluca | c. | ... | c. |
| Sagitta | r. | ... | c. |
| Crab zoea | — | ... | r. |
| Crab megalopa | — | ... | r. |
| Copepoda | c. | ... | ab. |
| Calanus | — | ... | r. |
| Pseudocalanus | — | ... | c. |
| Paracalanus | — | ... | ab. |
| Temora | c. | ... | c. |
| Centropages | c. | ... | r. |
| Oithona | c. | ... | c. |

Copepoda appeared to be more plentiful in Red Wharf Bay than at the entrance to the Ribble, and there was also a greater variety at the former place. The other constituents of the plankton differed very slightly in the two samples.

Two or more surface tow-nettings taken in the vicinity of Port Erin on the same day also show that the plankton may be almost identical at different spots at one period,

and that variation may be considerable at another date. On successive days one may even find that the quantity and kind of organisms undergo changes more or less marked.

On April 6th one tow-netting was taken in Port Erin Bay and another off the Calf Island. These show a certain amount of similarity.

| | Port Erin Bay. | | Off Calf Island. |
|---|---|---|---|
| Biddulphia | ab. | ... | ab. |
| Chætoceros | c. | ... | c. |
| Coscinodiscus | v.ab. | ... | v.ab. |
| Rhizosolenia | — | ... | r. |
| Acanthometra | r. | ... | — |
| Ceratium tripos | r. | ... | — |
| Ceratium fusus | r. | ... | — |
| Sagitta | r. | ... | — |
| "Mitraria" | r. | ... | r. |
| Nauplii of barnacles | c. | ... | — |
| Crab zoea | r. | ... | — |
| Copepoda | c. | ... | c. |
| Pseudocalanus | fr. | ... | fr. |
| Temora | fr. | ... | fr. |
| Centropages | r. | ... | r. |
| Acartia | fr. | ... | fr. |
| Oithona | fr. | ... | fr. |
| Whiting eggs | — | ... | r. |
| Gurnard eggs | r. | ... | r. |
| Sprat eggs | r. | ... | r. |
| Rockling eggs | r. | ... | — |
| Common Dragonet | r. | ... | r |

Diatoms and Copepoda had a uniform distribution in these areas at this time, but the other organisms mentioned were evidently limited to Port Erin Bay.

A few days later considerable variation was found in the plankton in Port Erin Bay and its immediate neighbourhood. On April 9th one sample was collected

in Port Erin Bay, and another just outside the seaward limit of this bay.

| | Port Erin Bay. | | Outside Port Erin Bay. |
|---|---|---|---|
| Biddulphia | ab. | ... | r. |
| Chætoceros | c. | ... | — |
| Coscinodiscus | v.ab. | ... | r. |
| Rhizosolenia | r. | ... | — |
| Ceratium tripos | r. | ... | — |
| Ceratium fusus | r. | ... | — |
| Sagitta | r. | ... | c. |
| Nauplii of barnacles | r. | ... | — |
| Copepoda | c. | ... | ab. |
| Calanus | — | ... | fr. |
| Pseudocalanus | fr. | ... | c. |
| Temora | fr. | ... | c. |
| Centropages | r. | ... | fr. |
| Acartia | fr. | ... | c. |
| Oithona | fr. | ... | fr. |
| Long Rough Dab eggs | — | ... | r. |
| Solenette eggs | fr. | ... | — |
| Whiting eggs | — | ... | r. |
| Ling eggs | — | ... | r. |
| Sprat eggs | — | ... | r. |
| Rockling eggs | — | ... | r. |

On this occasion Diatoms were confined practically to Port Erin Bay. Their relative abundance was the same as three days previously, and it will be noticed that a few *Rhizosolenia* were now found. Outside the limits of the bay we find an almost entire absence of Diatoms. One or two *Biddulphia* and *Coscinodiscus* were all that represented this important class of plankton. The Copepoda in the bay appeared to be fairly stationary, but out in the open sea they seemed to be increasing in quantity when compared with the sample taken off the Calf Island a few days before. *Sagitta* had also become tolerably common in the open, but still remained very scarce inside.

On August 24th collections of the open sea and inshore plankton were again taken. The open sea sample was collected three miles West of Bradda Head, and the shore one off Fleshwick. The latter place is about five miles due East from the former.

| | 3 Miles West of Bradda Head. | | Off Fleshwick. |
|---|---|---|---|
| Chætoceros | r. | ... | r. |
| Ceratium tripos | fr. | ... | c. |
| Noctiluca | — | ... | r. |
| Evadne | — | ... | r. |
| Podon | — | ... | r. |
| Crab zoea | r. | ... | r. |
| Crab megalopa | r. | ... | — |
| Copepoda | ab. | ... | ab. |
| Pseudocalanus | — | ... | fr. |
| Paracalanus | c. | ... | c. |
| Temora | — | ... | r. |
| Anomalocera | r. | ... | — |
| Parapontella | r. | ... | — |
| Isias | fr. | ... | r. |
| Acartia | fr. | ... | fr. |
| Oithona | c. | ... | c. |
| Oikopleura | fr. | ... | fr. |
| Weever eggs | 1 | ... | — |
| Quantity of Material | 3 c.c. | ... | 8 c.c. |

The most noteworthy difference between these two samples is in the quantity taken. The plankton inshore was evidently more abundant than in the open sea. There was also a slight change in the variety of organisms captured at the two places. Copepoda were just as numerous at the one station as at the other. *Anomalocera* and *Parapontella* were noted in the open sea but not inshore, while *Pseudocalanus* and *Temora* were found inshore only.

Inshore collections were taken on August 28th off Niarbyl and between Peel and Jurby, at a distance of about seven miles apart, and gave the following results:—

| | Off Niarbyl. | | Between Peel and Jurby. |
|---|---|---|---|
| Chætoceros | fr. | ... | c. |
| Ceratium tripos | fr. | ... | c. |
| Autolytus | c. | ... | r. |
| Crab zoea | r. | ... | r. |
| Crab megalopa | — | ... | r. |
| Podon | r. | ... | — |
| Evadne | r. | ... | — |
| Copepoda | c. | ... | c. |
| Calanus | r. | ... | r. |
| Pseudocalanus | r. | ... | — |
| Paracalanus | r. | ... | fr. |
| Temora | r. | ... | — |
| Centropages | r. | ... | r. |
| Isias | r. | ... | — |
| Acartia | fr. | ... | fr. |
| Oithona | c. | ... | c. |
| Oikopleura | fr. | ... | r. |
| Mackerel eggs | r. | ... | — |
| Rockling eggs | c. | ... | r. |
| Quantity of Material | 3 c.c. | ... | 13 c.c. |

These collections again show considerable variation in quantity of plankton at different places on the same day. Diatoms were more numerous off Peel than at Niarbyl, the other organisms also showed corresponding changes in distribution at the two stations.

On September 1st a sample of the plankton in the open sea four miles West of Bradda Head was taken, and also an inshore one off Niarbyl. The latter is about eight miles East-North-East from the former station.

| | 4 Miles West of Bradda Head. | | Off Niarbyl. |
|---|---|---|---|
| Chætoceros | fr. | ... | r. |
| Ceratium tripos | fr. | ... | c. |
| Sagitta | — | ... | r. |
| Autolytus | — | ... | r. |
| Crab zoea | r. | ... | c. |
| Crab megalopa | r. | ... | r. |
| Podon | — | ... | c. |
| Copepoda | r. | ... | ab. |
| Calanus | — | ... | fr. |
| Pseudocalanus | r. | ... | r. |
| Paracalanus | — | ... | r. |
| Centropages | r. | ... | fr. |
| Anomalocera | r. | ... | fr. |
| Labidocera | — | ... | r. |
| Acartia | fr. | ... | c. |
| Oithona | fr. | ... | fr. |
| Oikopleura | fr. | ... | c. |
| Sprat eggs | r. | ... | — |
| Rockling eggs | — | ... | r. |
| Quantity of Material | 1 c.c. | ... | 4 c.c. |

It is evident from the above results that the sea contained a more abundant plankton close inshore than in the open, and also that there was a much greater supply of Copepoda off Niarbyl than at the outside station. On comparing these results with previous ones obtained in the same areas, we find that, although there is not much change in quantity between the plankton off Niarbyl on August 28th and September 1st, the relative abundance of its constituents had altered at the later date. On the former date *Chætoceros* was fairly conspicuous and Copepoda only tolerably common. Four days later it will be noted that *Chætoceros* has almost disappeared and Copepoda become abundant. The collections taken West of Bradda Head, besides differing in quantity captured, also show a complete change in the relative abundance. The conditions are just the exact opposite from the

Narbyl plankton. On August 24th *Chætoceros* was very rare and Copepoda abundant, while on September 1st it was found that *Chætoceros* had become conspicuous and Copepoda scarce.

On September 10th tow-nettings were taken in the open sea, one nine miles West-North-West of Port Erin and another five miles West of Dalby. The latter station is about five miles due East from the former. The following are the results:—

| | 9 Miles W.N.W. of Port Erin. | | 5 Miles W. of Dalby. |
|---|---|---|---|
| Chætoceros | r. | ... | fr. |
| Coscinodiscus | r. | ... | — |
| Rhizosolenia | — | ... | r. |
| Ceratium tripos | r. | ... | fr. |
| Sagitta | r. | ... | r. |
| Autolytus | — | ... | r. |
| Podon | — | ... | r. |
| Evadne | — | ... | r. |
| Crab zoea | r. | ... | fr. |
| Crab megalopa | r. | ... | fr. |
| Copedoda | c. | ... | ab. |
| Calanus | fr. | ... | fr. |
| Pseudocalanus | — | ... | fr. |
| Paracalanus | — | ... | fr. |
| Temora | r. | ... | — |
| Centropages | fr. | ... | fr. |
| Anomalocera | fr. | ... | fr. |
| Acartia | r. | ... | fr. |
| Oithona | r. | ... | — |
| Oikopleura | — | ... | c. |
| Sprat eggs | r. | ... | — |
| Quantity of material | 0·25 c.c. | ... | 6 c.c. |

The quantity of plankton in the two areas evidently differed very much. One would naturally expect to find that the larger gathering would contain exactly the same kind of organisms that were present in the small catch, especially as the distance that divided the two areas was

comparatively short, had distribution been uniform. We find, however, that four of the constituents of the small catch were absent at a spot five miles away. It is obvious, then, that there was no uniformity in the plankton in these areas on September 10th.

A week later, September 17th, collections were taken eight miles North-West of Port Erin and five miles West of Cronk, which gave the following results:—

| | 8 Miles N.W. of Port Erin. | | 5 Miles W. of Cronk. |
|---|---|---|---|
| Biddulphia | r. | ... | r. |
| Chætoceros | — | ... | r. |
| Coscinodiscus | fr. | ... | r. |
| Ceratium tripos | fr. | ... | c. |
| Sagitta | r. | ... | — |
| Autolytus | — | ... | r. |
| Copepoda | r. | ... | c. |
| Centropages | r. | ... | r. |
| Anomalocera | — | ... | c. |
| Acartia | r. | ... | r. |
| Oithona | r. | ... | r. |
| Oikopleura | — | ... | fr. |
| Sprat eggs | — | ... | r. |
| Quantity of material | 0·5 c.c. | ... | 3 c.c. |

The difference in the constituents and the quantity of plankton taken are well marked in this instance. The distribution was probably more uniform than on September 10th, as only one of the organisms in the small collection was absent from the larger one. The first station in the above list is about three miles East-North-East of the area, nine miles West-North-West of Port Erin, visited on September 10th. A comparison of the plankton taken at these two places on the dates given shows that considerable changes had taken place in the course of a week. The amount of plankton in the water was about the same on the two dates. On September 10th *Chætoceros* and *Coscinodiscus*

represented the Diatoms; both were scarce. A week later *Chætoceros* was absent, *Coscinodiscus* had become more numerous and *Biddulphia* was found. Copepoda were tolerably plentiful the week previous, and such forms as *Calanus* and *Anomalocera* were quite conspicuous. Six genera were then present. On September 17th the Copepoda had almost disappeared. Only three of the genera observed on the former visit were found, and these were represented by a few individuals.

We sometimes find that the pelagic life of the sea undergoes great changes in a very short time. Organisms that may be abundant one day are often quite absent on the next, and collections taken in the same place on successive days rarely give identical results.

On August 22nd and 23rd the sea North of the Calf Island was investigated, and the following organisms were found:—

| | August 22. | | August 23. |
|---|---|---|---|
| Chætoceros | r. | ... | r. |
| Crab megalopa | r. | ... | — |
| Copepoda | r. | ... | c. |
| Paracalanus | v.r. | ... | — |
| Temora | v.r. | ... | — |
| Acartia | v.r. | ... | — |
| Oithona | r. | ... | c. |
| Oikopleura | c. | ... | — |
| Quantity of material | 2 c.c. | ... | 1 c.c. |

The first visit gave a greater number of organisms than the second. Copepoda, although very scarce on the 22nd, were represented by four genera. Next day this group was tolerably common, yet only one genus was noted.

Collections taken off Niarbyl on August 27th and 28th and September 1st showed differences of various kinds.

| | August 27. | August 28. | Sept. 1. |
|---|---|---|---|
| Chætoceros | c. | fr. | r. |
| Ceratium tripos | c. | fr. | c. |
| Sagitta | — | — | r. |
| Autolytus | — | r. | r. |
| Crab zoea | — | r. | c. |
| Crab megalopa | — | — | r. |
| Podon | — | c. | c. |
| Evadne | — | c. | — |
| Copepoda | v.ab. | c. | ab. |
| Calanus | — | r. | fr. |
| Pseudocalanus | r. | r. | r. |
| Paracalanus | fr. | r. | r. |
| Temora | r. | r. | fr. |
| Centropages | r. | r. | fr. |
| Anomalocera | r. | — | fr. |
| Parapontella | r. | r. | — |
| Labidocera | — | r. | r. |
| Isias | r. | r. | — |
| Acartia | fr. | fr. | c. |
| Oithona | c. | c. | fr. |
| Oikopleura | fr. | fr. | c. |
| Mackerel eggs | — | r. | — |
| Rockling eggs | — | r. | r. |
| Quantity of material | 11 c.c. | 3 c.c. | 4 c.c. |

On August 27th the pelagic life was far more abundant than at the later dates. The Copepoda varied in genera and relative abundance each visit. *Podon* and *Evadne*, although tolerably common on August 28th were quite absent on the previous day, and only *Podon* was noted on September 1st. *Sagitta* was not found either on August 27th or 28th, but was represented by a few specimens on September 1st. Crab Zoea were found to be tolerably common on September 1st, scarce on August 28th, and entirely absent on the 27th. Megalopa were only noted on September 1st.

Tow-nettings taken at longer intervals in the same spot frequently show extreme variations. This is well

illustrated in the results obtained from collections made in Port Erin Bay on September 25th, 26th, 27th and on October 4th.

| | Sept. 25-27. | | Oct. 4. |
|---|---|---|---|
| Biddulphia | r. | ... | v.r. |
| Chætoceros | ab. | ... | v.r. |
| Coscinodiscus | r. | ... | v.r. |
| Rhizosolenia | fr. | ... | v.r. |
| Ceratium tripos | fr. | ... | r. |
| Pleurobrachia | r. | ... | — |
| Sagitta | c. | ... | r. |
| Copepoda | c. | ... | v.ab. |
| Calanus | r. | ... | r. |
| Pseudocalanus | fr. | ... | c. |
| Paracalanus | fr. | ... | c. |
| Temora | fr. | ... | fr. |
| Acartia | c. | ... | c. |
| Oithona, | fr. | ... | c. |
| Oikopleura | fr. | ... | r. |
| Quantity of Material | 25 c.c. | ... | 12 c.c. |

On September 25th the sea water was filled with Diatoms, chiefly *Chætoceros*. *Sagitta* were tolerably common, Copepoda were fairly numerous, the most plentiful being *Acartia*. During the next two days similar conditions prevailed, not only in Port Erin Bay itself, but in all the outer area from Bradda Head to Bay Fine. On October 4th, just a week later, the conditions had completely changed. Diatoms had almost vanished. only a few individuals belonging to the genera mentioned were found. Copepoda had, however, become extremely abundant. *Pseudocalanus*, *Paracalanus*, *Acartia*, and *Oithona* all being tolerably common. The water was less densely populated with organisms on October 4th than between September 25th and 27th.

The table opposite gives the results obtained from the tow-nettings taken in the vicinity of Port Erin from

| | 4 miles W. of Port Erin. 22 July. | 4-5 miles W. of Port Erin. 25 July. | Niarbyl Bay. 27 July. | Bay Fine. Hensen net. 28 July | Off Niarbyl. 30 July. | 7-8 miles N.W. of Port Erin. 6 August. | N. of Calf Island. 9 August. | N. of Calf Island. 9 August. | 2 miles N. of Calf. 10 August. | 2 miles N. of Calf. 10 August. | Off Calf. 13 August. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth in fathoms | 0 | 20 | 0 | 5 | 5 | 10 | 0 | 5-7 | 0 | 5-7 | 0 |
| Quantity in cubic centimetres | 7 | 7 | 5 | 9 | 17 | 7 | 5 | 1 | 1 | 1 | 8 |
| **Organisms.** | | | | | | | | | | | |
| Biddulphia mobiliensis | | | | | | | | | | | |
| Chætoceros contortum | | | | | | | | | | | |
| Chætoceros decipiens | r. | | | | | | | r. | | | r. |
| Chætoceros teres | | | | | | | | | | | |
| Coscinodiscus concinnus | | | | | | | | | | | |
| Rhizosolenia semispina | | | | | | | | | | | |
| Rhizosolenia shrubsolei | | | | | | | | | | | |
| Ceratium furca | | | | | | | | | | | r. |
| Ceratium fusus | r. | | | | | | | | | | |
| Ceratium tripos | c. | | c. | fr. | | | fr. | r. | r. | r. | c. |
| Tintinnopsis campanula | | | | | | | | | | | |
| Noctiluca miliaris | | | | | | | | | | | |
| Pleurobrachia pileus | 1 | | | | | | | | | | 1 |

July 22nd to November 5th, and includes the special work on the s.y. "Madge."

It may be argued that the plankton near the land is more susceptible to sudden changes than that of the open sea; that winds, currents and other agencies have great effect on local distribution; that the further one proceeds away from land influences the results will be found to be more equal. Against this it may be stated that regions where winds and currents have no effect are difficult to find, and one has to make the best of his opportunities. My own experience, from a long dealing with plankton from many regions, is that one very rarely finds exactly the same kinds of organisms or the same relative abundance in collections taken on the same day.

A recent expedition with the Hensen net across the Irish Sea, from Piel Gas Buoy to the Isle of Man, gave very interesting results. On November 13th, starting from Piel Gas Buoy and proceeding in a north-westerly direction to the Isle of Man, four hauls were made. The first haul was taken six miles from the gas buoy, the second fifteen miles, the third twenty-four miles, and the fourth forty-two miles off the buoy. Each of the three last hauls was made nine miles away from the preceding one. The net was lowered to a depth of ten fathoms at each station and then drawn slowly to the surface. The water everywhere was found to be teeming with Diatoms. The first haul contained a great abundance of *Chætoceros* (four species) and *Rhizosolenia*. In the second haul *Coscinodiscus* was the chief constituent. The third haul contained an abundance of *Eucampia* and *Rhizosolenia*. The fourth haul was very similar to the first. Copepoda were comparatively scarce throughout the traverse, and consisted mainly of *Paracalanus* and *Oithona*. The first haul contained one *Calanus* and six *Temora*. *Temora* was

not taken again, and the second and third hauls had no *Calanus*. The fourth haul contained eight *Calanus*. Amongst other things, *Noctiluca* and *Sagitta* were tolerably common in the four hauls.

The cruise was continued to the West side of the Isle of Man. Six miles North from Peel another haul was taken, which showed a complete change in constituents. Three *Sagitta* and sixteen *Calanus* were found. *Pseudocalanus*, *Acartia* and *Oithona* were tolerably common. Four genera of Diatoms, represented in each case by a very few specimens, a few larval Polychætes, *Ceratium tripos* and *C. fusus*, and "*Mitraria*" but no *Noctiluca*, were taken. It is probable that the few Diatoms present in the fifth haul had remained attached to the meshes of the net since the previous haul. A collection taken with an ordinary surface tow-net near the same spot did not contain a single Diatom. Otherwise the constituents found by this net were the same as those contained in the Hensen net collection. The quantity of material taken each time the Hensen net was hauled differed in every instance.

The colour of the material collected in hauls I.-IV. varied from a decided green to a greenish yellow. The first haul, from its characteristic colour was obviously mainly composed of Diatoms. Haul V. was almost white in colour.

The following table shows the results of the five hauls with the Hensen net:—

## Results of Five Hauls taken with the Hensen Vertical Net on the same day, November 19th, 1906, in different parts of the Irish Sea.

| | 6 miles N.W. from Piel Gas Buoy. | 15 miles N.W. from Piel Gas Buoy. | 24 miles N.W. from Piel Gas Buoy. | 32 miles N.W. from Piel Gas Buoy. | 6 miles N.W. from Peel, Isle of Man |
|---|---|---|---|---|---|
| Quantity in cubic centimetres | 4 | 1 | 2 | 2·5 | 0·5 |
| Asterionella bleakleyi | fr. | r. | r. | fr. | — |
| Biddulphia mobiliensis | r. | r. | r. | fr. | v.r. |
| Chætoceros constrictum | c. | fr. | fr. | c. | — |
| Chætoceros debile | fr. | fr. | fr. | fr. | — |
| Chætoceros decipiens | c. | fr. | fr. | c. | v.r. |
| Chætoceros teres | fr. | fr. | fr. | fr. | — |
| Coscinodiscus concinnus | fr. | ab. | fr. | fr. | v.r. |
| Ditylium brightwelli | r. | r. | r. | r. | — |
| Eucampia zoodiacus | c. | fr. | ab. | c. | — |
| Melosira borreri | c. | fr. | fr. | c. | — |
| Rhizosolenia semispina | ab. | fr. | ab. | ab. | v.r. |
| Rhizosolenia shrubsolei | c. | fr. | fr. | c. | — |
| Ceratium furca | fr. | fr. | fr. | fr. | — |
| Ceratium fusus | c. | fr. | fr. | fr. | r. |
| Ceratium tripos | c. | fr. | c. | fr. | r. |
| Tintinnopsis campanula | r. | — | — | — | — |
| Noctiluca miliaris | fr. | fr. | fr. | fr. | — |
| Pleurobrachia pileus | 1 | — | 2 | — | — |
| Sagitta bipunctata | c. | 50 | c. | c. | 3 |
| Larval Polychaeta | r. | r. | r. | r. | r. |
| "Mitraria" | r. | r. | r. | r. | r. |
| Calanus helgolandicus | 1 | — | — | 8 | 16 |
| Pseudocalanus elongatus | r. | fr. | fr. | fr. | fr. |
| Paracalanus parvus | fr. | c. | c. | fr. | c. |
| Temora longicornis | 6 | — | — | — | — |
| Acartia clausi | r. | r. | fr. | fr. | fr. |
| Oithona similis | fr. | fr. | fr. | fr. | fr. |
| Oikopleura | r. | r. | r. | r. | r. |
| Copepod nauplii | fr. | r. | r. | r. | r. |

The following tables show the occurrence from month to month of the various organisms identified in the plankton collected from the areas named in 1906:—

## January.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Biddulphia mobiliensis | ..... | ..... | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Chætoceros contortum | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Chætoceros criophilum | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Chætoceros decipiens | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Chætoceros teres | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Coscinodiscus concinnus | ..... | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Rhizosolenia semispina | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Rhizosolenia setigera | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Rhizosolenia shrubsolei | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Ceratium fusus | + | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Ceratium tripos | + | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Acanthometra sp. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Noctiluca miliaris | + | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Pleurobrachia pileus | ..... | + | + | + | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Sagitta bipunctata | + | + | ..... | + | + | + | ..... | ..... | ..... | + | ..... | ..... | + |
| Autolytus prolifer | ..... | ..... | + | + | + | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Tomopteris onisciformis | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Larval Polychæta | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| "Mitraria" | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | + |
| Crab zoea | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Mysis stage of Crangon | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Young Mysis | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Hyperia galba | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Parathemisto oblivia | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Paramphithöe bicuspis | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Iphimedia obesa | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Paratylus swammerdamii | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Nyctiphanes norvegica | ..... | ..... | ..... | + | + | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Podon intermedium | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Calanus helgolandicus | ..... | ..... | + | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | + |
| Pseudocalanus elongatus | + | ..... | + | + | + | + | ..... | ..... | ..... | + | ..... | ..... | + |
| Paracalanus parvus | + | + | + | + | + | + | ..... | ..... | ..... | + | ..... | ..... | + |
| Temora longicornis | + | ..... | + | + | + | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Centropages hamatus | + | ..... | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Anomalocera pattersoni | ..... | ..... | ..... | ..... | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Acartia clausi | + | + | + | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Oithona similis | + | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Oithona nana | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Euterpina acutifrons | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Copepod nauplii | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Oikopleura | ..... | ..... | + | + | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | + |
| Young Gasteropods | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Young Lamellibranchs | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + |
| Fish eggs | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Fish larvæ | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 13 | 11 | 19 | 26 | 8 | 18 | — | — | — | 14 | — | — | 2 |

## February.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ia mobiliensis ... | + | ..... | ..... | + | ..... | + | ..... | ..... | + | + | ..... | ..... | + | ..... |
| ia aurita ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| os contortum ... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| os criophilum ... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| os decipiens ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| os teres ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| iscus concinnus ... | + | ..... | ..... | + | ..... | ..... | ..... | ..... | + | + | ..... | ..... | + | ..... |
| iscus grani ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| enia semispina ... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| enia setigera ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| lenia shrubsolei ... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| n furca ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| n fusus ..... | + | ..... | ..... | + | + | ..... | ..... | ..... | ..... | + | ..... | ..... | + | ..... |
| n tripos ..... | + | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| metra sp. ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| a miliaris ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| achia pileus ..... | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| d gonophores ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| ipunctata ..... | + | + | ..... | + | ..... | + | ..... | ..... | + | + | + | ..... | + | ..... |
| s prolifer ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | + | + | + | ..... | ..... | ..... |
| ris onisciformis ... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | + | ..... | + | ..... | + | ..... |
| olychæta ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| ia " ..... | + | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| a ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| age of Crangon ... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| dysis ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| anes norvegica ... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| e pulchra ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| galba ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| misto oblivia ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| heloglandicus ..... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | + | + | + | ..... | + | ..... |
| alanus elongatus ... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | + | ..... | + | ..... | + | ..... |
| nus parvus ..... | + | + | ..... | + | ..... | + | ..... | ..... | + | + | + | ..... | + | ..... |
| longicornis ..... | ..... | + | ..... | + | ..... | + | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... |
| ages hamatus ..... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | + | ..... | + | ..... | ..... | ..... |
| ages typicus ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| cera pattersoni ... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| discaudata ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| clausi..... | + | + | ..... | + | + | + | ..... | ..... | ..... | + | + | ..... | ..... | ..... |
| similis ..... | + | ..... | ..... | + | ..... | + | ..... | ..... | ..... | + | ..... | ..... | + | ..... |
| nana ..... | + | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| a acutifrons ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| nauplii ..... | ..... | ..... | ..... | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| of barnacles ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| ra ..... | ..... | ..... | ..... | + | + | ..... | ..... | ..... | ..... | + | ..... | ..... | + | ..... |
| eggs ..... | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| lasteropods ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| amellibranchs..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | + | ..... | ..... | + | ..... |
| s ..... | ..... | ..... | ..... | + | + | + | ..... | ..... | + | ..... | + | ..... | + | ..... |
| e ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| | 13 | 5 | — | 22 | 7 | 21 | — | — | 17 | 11 | 15 | — | 25 | — |

## March.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asterionella bleakleyi | | | | | | | | | + | | | |
| Bellerochoe malleus | + | | | | | | | | | | | |
| Bid lulphia mobiliensis | + | | | + | + | | | | + | | | |
| Biddulphia aurita | + | | | + | | | | | | | | |
| Chætoceros contortum | | | | | | | | | | | | |
| Chætoceros decipiens | | | | | | | | | | | | |
| Coscinodiscus concinnus | | | | | + | + | | | + | | | |
| Rhizosolenia semispina | | | | | | + | | | + | | | |
| Ceratium furca | | | | | | | | | | | | |
| Ceratium fusus | + | | | + | | + | | | + | | | |
| Ceratium tripos | | | | + | | | | | + | | | |
| Acanthometra sp. | | | | | | | | | | | | |
| Pleurobrachia pileus | + | | | + | | | | | | | | |
| Medusoid gonophores | | | | | | | | | + | | | |
| Alcyonium eggs | | | | | | | | | + | | | |
| Echinoderm larvæ | | | | | | | | | | | | |
| Sagitta bipunctata | | | | + | + | + | | | + | | | |
| Autolytus prolifer | | | | + | + | + | | + | | | | |
| "Mitraria" | | | | | + | + | | | | | | |
| Crab zoea | | | | | | + | | | + | | | |
| Mysis stage of Crangon | + | | | + | | + | | | | | | |
| Eurydice pulchra | | | | + | | | | | + | | | |
| Bathyporeia pelagica | | | | + | | | | | | | | |
| Ampelisca spinipes | | | | + | | | | | | | | |
| Apherusa bispinosa | | | | + | | | | | | | | |
| Perioculodes longimanus | | | | + | | | | | | | | |
| Phoxocephalus fultoni | | | | + | | | | | | | | |
| Podon intermedium | | | | | | + | | | | | | |
| Calanus helgolandicus | | | | | | | | | + | | | |
| Pseudocalanus elongatus | + | | | + | | + | | | + | | | |
| Paracalanus parvus | | | | + | | | | + | + | | | |
| Temora longicornis | | | | + | + | + | | | + | | | |
| Centropages hamatus | | | | + | | + | | | + | | | |
| Acartia clausi | | | | + | + | + | | + | + | | | |
| Oithona similis | | | | + | | | | | | | | |
| Oithona nana | | | | | | | | | | | | |
| Caligus rapax | | | | + | | + | | | + | | | |
| Copepod nauplii | + | | | | + | + | | | + | | | |
| Nauplii of barnacles | + | | | | + | + | | | | | | |
| Ostracod stage of barnacles | + | | | | + | + | | | | | | |
| Oikopleura | | | | + | | + | | + | + | | | |
| Ascidian eggs | + | | | + | | + | | + | + | | | |
| Young Gasteropods | | | | | | + | | | | | | |
| Fish eggs | + | | | + | + | + | | + | + | | | |
| Fish larvæ | | | | + | | + | | | + | | | |
| | 12 | — | — | 25 | 11 | 22 | — | 6 | 23 | — | — | — |

## April.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asterionella bleakleyi | | | | | + | | | | | | | | | |
| Biddulphia mobiliensis | | | | | + | + | | | | + | | | + | |
| Chætoceros contortum | | | | | | | | | | | | | + | |
| Chætoceros criophilum | | | | | | | | | | | | | + | |
| Chætoceros decipiens | | | | | | | | | | | | | + | |
| Chætoceros teres | | | | | | | | | | | | | + | |
| Coscinodiscus concinnus | | | | | + | + | | + | | + | | | + | |
| Rhizosolenia semispina | | | | | | | | + | | + | | | | |
| Rhizosolenia setigera | | | | | | | | + | | + | | | | |
| Rhizosolenia shrubsolei | | | | | | | | + | | + | | | | |
| Thalassiothrix curvata | | | | | | | | | | | | | + | |
| Ceratium furca | | | | | | | | + | | | | | + | |
| Ceratium fusus | | | | | | | | + | | + | | | + | |
| Ceratium tripos | | | | | | | | + | | + | | | + | |
| Acanthometra sp. | | | | | | | | | | | | | + | |
| Alcyonium eggs | | | | | | | | + | | + | | | + | |
| Sagitta bipunctata | | | | + | + | + | | + | | | | | + | |
| Autolytus prolifer | | | | | | + | | + | | + | | | | |
| Larval Polychaeta | | | | | | | | | | | | | + | |
| "Mitraria" | | | | | | + | | | | | | | + | |
| Crab zoea | | | | | | | | + | | + | | | + | |
| Crab megalopa | | | | | | | | + | | | | | | |
| Mysis stage of Crangon | | | | | | | | + | | | | | | |
| Pasiphea sivado | | | | | | | | + | | | | | | |
| Eurydice pulchra | | | | | | + | | | | | | | | |
| Rhodorella truncatula | | | | | | | | + | | | | | | |
| Rhodorellopsis deformis | | | | | | | | + | | | | | | |
| Calanus helgolandicus | | | | | | | | | | + | | | + | |
| Pseudocalanus elongatus | | | | | | + | | + | | | | | + | |
| Paracalanus parvus | | | | | | | | + | | + | | | + | |
| Temora longicornis | | | | + | + | + | | + | | + | | | + | |
| Centropages hamatus | | | | + | | + | | | | | | | + | |
| Acartia clausi | | | | + | + | + | | + | | + | | | + | |
| Oithona similis | | | | | | | | | | | | | + | |
| Oithona nana | | | | | | | | | | | | | + | |
| Copepod nauplii | | | | | | + | | + | | + | | | + | |
| Nauplii of barnacles | | | | | + | + | | | | | | | + | |
| Cirracod stage of barnacles | | | | | + | + | | | | | | | + | |
| Chaetopleura | | | | | | | | + | | + | | | + | |
| Annelian eggs | | | | | | | | + | | + | | | | |
| Fish eggs | | | | | + | + | | + | | + | | | + | |
| Fish larvæ | | | | | | | | | | | | | | |
| | — | — | — | 4 | 9 | 14 | — | 24 | — | 18 | — | — | 29 | — |

## May.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. | Loch Bar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asterionella bleakleyi | + | | | | | | | | | | | | | |
| Biddulphia mobiliensis | + | + | + | + | + | | | + | | | | | + | |
| Chætoceros contortum | | | | | | | | | | | | | + | |
| Chætoceros criophilum | | | | | | | | | | | | | + | |
| Chætoceros decipiens | | | | | | | | | | | | | + | |
| Chætoceros teres | | | | | | | | | | | | | + | |
| Coscinodiscus concinnus | + | + | + | + | + | + | | + | | + | | | + | |
| Coscinodiscus grani | | + | | | | | | | | | | | | |
| Rhizosolenia semispina | + | + | + | + | + | + | | + | | + | | + | + | |
| Rhizosolenia setigera | + | + | + | + | + | | | + | | | | | + | |
| Rhizosolenia shrubsolei | + | + | | | + | | | + | | | | | | |
| Ceratium furca | + | | | | | + | | | | + | | | | |
| Ceratium fusus | + | + | + | + | | | | + | | + | | + | | |
| Ceratium tripos | + | + | + | + | | | | + | | + | | | + | |
| Noctiluca miliaris | + | | + | | | | | | | | | | | |
| Pleurobrachia pileus | + | + | + | + | | + | + | + | | | | | + | |
| Sarsia tubulosa | | | | | | + | + | | | | | | | |
| Medusoid gonophores | | + | | | | | + | | | + | | | + | |
| Alcyonium eggs | + | + | + | | | + | | + | | | | | + | |
| Sagitta bipunctata | + | + | + | + | | + | + | + | | + | | | + | |
| Autolytus prolifer | | | | | + | + | + | | | + | | | + | |
| Larval polychæta | | | | + | | | | | | | | | | |
| "Mitraria" | | + | | + | | + | | | | + | | | | |
| Crab zoea | | + | + | + | + | + | + | | | + | | + | | |
| Crab megalopa | | + | | + | | + | + | | | | | | | |
| Mysis stage of Crangon | | + | | + | | + | | | | + | | + | | |
| Larval Nephrops | | | | + | | + | + | + | | | | | | |
| Nyctiphanes norvegica | | | | + | | | + | | | | | | | |
| Podon intermedium | | | | + | | + | | | | + | | | + | |
| Evadne nordmanni | | + | | | | + | | | | | | | | |
| Calanus helgolandicus | | | | | + | | + | | | | | | + | |
| Pseudocalanus elongatus | | | | | | + | + | + | | | | | + | |
| Paracalanus parvus | | + | | + | | + | + | | | | | + | | |
| Temora longicornis | | + | | + | + | + | + | + | | + | | | + | |
| Centropages hamatus | | | | + | + | + | + | + | | | | | | |
| Centropages typicus | | | | | | + | + | | | + | | | + | |
| Anomalocera pattersoni | | + | | | | + | | | | | | | + | |
| Isias clavipes | | | | | | + | | | | | | | | |
| Acartia clausi | | + | | + | + | + | + | + | | + | | + | + | |
| Acartia discaudata | | | | | | + | | | | | | | | |
| Oithona similis | | | | | | | | | | | | | + | |
| Euterpina acutifrons | | | | | | | | | | | | | + | |
| Copepod nauplii | + | + | + | + | + | + | | + | | | | + | + | |
| Nauplii of barnacles | | | | + | + | + | | + | | | | | + | |
| Ostracod stage of barnacles | | | | + | + | + | | | | | | | + | |
| Oikopleura | + | + | | + | | + | | | | + | | | + | |
| Ascidian eggs | | + | + | + | | | | | | + | | | | |
| Young Gasteropods | | | | | | | | | | | | | + | |
| Young Lamellibranchs | | + | | | | | | | | | | | + | |
| Fish eggs | | + | | + | + | + | + | + | | + | | + | + | |
| Fish larvæ | | + | | + | | + | + | + | | | | | | |
| | 15 | 27 | 13 | 27 | 15 | 30 | 18 | 19 | — | 18 | — | 8 | 30 | — |

## June.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Biddulphia mobiliensis | | | | | | | | | | | | | + | |
| Biddulphia aurita | | | | | | + | | | | | | | | |
| Chætoceros decipiens | | | | | | | | | | | | | + | |
| Eucampia zoodiacus | | | | | | | | | | | | | + | |
| Melosira borreri | | | | | | | | | | | | | + | |
| Rhizosolenia semispina | | | | | | + | | | | + | | | + | |
| Rhizosolenia setigera | | | | | | | | | | | | | + | |
| Ceratium fusus | | | | + | | + | | | | + | | | | |
| Ceratium tripos | | | | + | | + | | | | + | | | + | |
| Noctiluca miliaris | | | | + | | | | | | | | | | |
| Pleurobrachia pileus | | + | | + | | + | + | | | + | | | | |
| Medusoid gonophores | | | | + | | | + | | | + | | | + | |
| Sarsia tubulosa | | | | | | | + | | | | | | | |
| Echinoderm larvæ | | | | | | + | | | | | | | | |
| Sagitta bipunctata | | + | | | | + | + | | | + | | | | |
| Autolytus prolifer | | | | | | + | + | | | | | | | |
| "Mitraria" | | + | | | | + | | | | | | | | |
| Crab zoea | | + | | + | | + | + | | | + | | | | |
| Crab megalopa | | + | | | | + | + | | | + | | | | |
| Mysis stage of Crangon | | + | | + | | + | | | | | | | | |
| Podon intermedium | | | | | | + | | | | | | | | |
| Evadne nordmanni | | + | | | | + | | | | | | | | |
| Calanus helgolandicus | | | | | | + | + | | | | | | + | |
| Pseudocalanus elongatus | | | | + | | + | + | | | + | | | | |
| Paracalanus parvus | | + | | | | + | + | | | | | | | |
| Temora longicornis | | + | | + | | + | + | | | + | | | + | |
| Centropages hamatus | | | | + | | + | + | | | | | | | |
| Centropages typicus | | | | | | + | + | | | | | | | |
| Anomalocera pattersoni | | + | | | | + | | | | | | | | |
| Labidocera wollastoni | | + | | | | | | | | | | | | |
| Acartia clausi | | + | | + | | + | + | | | + | | | | |
| Acartia discaudata | | | | | | + | | | | | | | | |
| Oithona similis | | | | | | + | | | | | | | + | |
| Copepod nauplii | | + | | | | | | | | | | | + | |
| Nauplii of barnacles | | + | | | | | | | | | | | | |
| Ostracod stage of barnacles | | + | | | | | | | | | | | | |
| Pteropleura | | + | | + | | + | + | | | + | | | + | |
| Ascidian eggs | | | | | | + | | | | | | | | |
| Young Gasteropods | | | | | | + | | | | | | | + | |
| Young Lamellibranchs | | | | | | + | | | | | | | + | |
| Fish eggs | | + | | + | | + | + | | | + | | | | |
| Fish larvæ | | + | | | | + | + | | | + | | | | |
| | — | 18 | — | 13 | — | 30 | 17 | — | — | 14 | — | — | 15 | — |

## July.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Ruyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bellerochea malleus | | | | | + | | | | | | | | + |
| Biddulphia mobiliensis | | + | | | + | + | | | + | | | | + |
| Chætoceros decipiens | | | | | | | | | | | | | + |
| Eucampia zoodiacus | | | | | | | | | | | | | + |
| Melosira borreri | | | | | | | | | | | | | + |
| Rhizosolenia semispina | | + | | | | | | | | | | | + |
| Rhizosolenia setigera | | | | | | | | | | | | | + |
| Ceratium furca | | + | | | | | | | + | | | | |
| Ceratium fusus | | + | + | | | | | | + | | | | |
| Ceratium tripos | + | + | + | | | + | | | + | | | | + |
| Noctiluca miliaris | + | + | + | + | + | + | | | + | | | | |
| Pleurobrachia pileus | | + | | + | + | | | | + | | | | |
| Young Aurelia | | | | | | | | | | | | | + |
| Medusoid gonophores | | | | + | | | | | | | | | + |
| Echinodern larvæ | | + | | | | | | | | | | | |
| Sagitta bipunctata | | + | | | | + | | | | | | | + |
| Autolytus prolifer | | | | | | | | | | | | | + |
| Tomopteris onisciformis | | | | | | | | | | | | | + |
| Larval Polychæta | | + | | + | | | | | | | | | + |
| "Mitraria" | | + | | + | | | | | | | | | |
| Crab zoea | + | + | | + | + | + | | | + | | | | + |
| Crab megalopa | + | | | + | + | + | | | + | | | | + |
| Mysis stage of Crangon | | | | + | + | + | | | | | | | + |
| Young Mysis | | | | + | | | | | | | | | |
| Larval Squilla | | | | | | + | | | | | | | |
| Larval Lobsters | | | | | | + | | | | | | | |
| Podon intermedium | | + | | + | | + | | | | | | | + |
| Evadne nordmanni | | + | | | | + | | | + | | | | + |
| Calanus helgolandicus | | | | | | + | | | | | | | + |
| Pseudocalanus elongatus | | | | | | + | | | + | | | | + |
| Paracalanus parvus | | | | | | + | | | | | | | + |
| Temora longicornis | + | + | + | + | + | + | | | | | | | + |
| Centropages hamatus | + | + | + | + | + | + | | | + | | | | + |
| Centropages typicus | | | | | | + | | | | | | | |
| Anomalocera pattersoni | + | + | | | + | + | | | + | | | | + |
| Labidocera wollastoni | | + | | | | + | | | | | | | |
| Isias clavipes | | | | | | + | | | | | | | + |
| Acartia clausi | | + | | + | + | + | | | + | | | | + |
| Acartia discaudata | | | | | | + | | | | | | | |
| Oithona similis | | | | | | | | | | | | | + |
| Copepod nauplii | | | | | | | | | | | | | + |
| Ostracod stage of barnacles | | | | | | + | | | | | | | |
| Oikopleura | + | + | | + | | | | | + | | | | + |
| Ascidian eggs | | + | | | | | | | | | | | |
| Young Lamellibranchs | | + | | | | | | | | | | | + |
| Young Gasteropods | | | | | | | | | | | | | + |
| Fish eggs | + | + | | + | + | + | | | + | | | | + |
| Fish larvæ | + | + | + | | + | + | | | | | | | |
| | 10 | 23 | 6 | 15 | 12 | 24 | — | — | 14 | — | — | — | 33 |

## August.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Bahama Bank. | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| aradoxa | ..... | ..... | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| mobiliensis | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| aurita | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| decipiens | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| eriata | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| ia semispina | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| urca | ..... | ..... | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| usus | ..... | + | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| ripos | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| miliaris | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| chia pileus | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| gonophores | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| punctata | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| prolifer | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| s onisciformis | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| lychæta | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| n | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... |
| | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| dopa | ..... | + | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| e of Crangon | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| tea | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| nilla | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| sto oblivia | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| rina | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| pinigera | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| ulchra | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| rmedium | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| rdmanni | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| lgolandicus | ..... | ..... | ..... | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| nus elongatus | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| s parvus | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| gicornis | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| s hamatus | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| s typicus | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| rmata | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| es | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| ra pattersoni | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| wollastoni | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| biancoi | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| la brevicornis | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| usi | ..... | + | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | + | + | ..... |
| caudata | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| nilis | ..... | ..... | + | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| ax | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| suplii | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| tage of barnacles | ..... | ..... | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | ..... | ..... | + | + | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| teropods | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| nellibranchs | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... |
| | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | — | 10 | 14 | 26 | — | 24 | — | — | — | — | — | 10 | 35 | — |

## September.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Reel Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Laxey Bay. | Lune Deep. | Port Erin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asterionella bleakleyi | + | + | + | | | | | | | | | | |
| Bacillaria paradoxa | + | + | + | + | | | | | | | | | |
| Bacteriastrum delicatulum | + | + | + | | | | | | | | | | |
| Bellerochoe malleus | + | + | | | | | | | | | | | |
| Biddulphia mobiliensis | | | | + | | | | | | | | | + |
| Chætoceros contortum | | | | | | | | | | | | | + |
| Chætoceros decipiens | | + | + | + | + | | | | | | | | + |
| Chætoceros teres | | | | | | | | | | | | | + |
| Coscinodiscus concinnus | + | + | + | | | | | | | | | | + |
| Coscinodiscus grani | + | + | + | | | | | | | | | | |
| Nitzschia seriata | + | + | + | | | | | | | | | | |
| Rhizosolenia semispina | | + | + | + | | | | | | | | | + |
| Rhizosolenia setigera | | + | | | | | | | | | | | |
| Rhizosolenia shrubsolei | + | + | + | + | | | | | | | | | + |
| Ceratium furca | + | + | + | + | | | | | | | | | + |
| Ceratium fusus | + | + | + | + | | | | | | | | | + |
| Ceratium tripos | + | + | + | + | | | | | | | | | + |
| Tintinnopsis campanula | + | + | + | | | | | | | | | | + |
| Noctiluca miliaris | + | + | + | + | | + | | | | | | | |
| Pleurobrachia pileus | + | + | + | + | + | | | | | | | | + |
| Larval Aurelia | + | | | | | | | | | | | | |
| Medusoid gonophores | | + | + | + | + | + | | | | | | | + |
| Larval Echinoderms | | | | | | | | | | | | | + |
| Sagitta bipunctata | + | + | + | + | + | + | | | | | + | | + |
| Autolytus prolifer | | | | | | | | | | | + | | + |
| Tomopteris onisciformis | | | | + | | | | | | | | | + |
| Larval Polychæta | | | | + | | | | | | | | | + |
| "Mitraria" | | | | + | | + | | | | | | | + |
| Larval Lobster | | | | | | | | | | | | | + |
| Crab zoea | + | | + | | + | + | | | | | + | | + |
| Crab megalopa | + | + | + | + | | + | | | | | + | | + |
| Mysis stage of Crangon | + | + | | + | + | | | | | | + | | + |
| Mysis | + | + | | + | | | | | | | | | + |
| Larval Cumacea | | | | | | | | | | | | | + |
| Eurydice spinigera | | | | | | + | | | | | | | |
| Eurydice inermis | | | | | | | | | | | | | + |
| Idotea marina | | | | | | + | | | | | | | + |
| Hyperia galba | | | | + | | | | | | | | | |
| Parathemisto oblivia | | | | + | | | | | | | | | |
| Apherusa bispinosa | | | | | | | | | | | | | + |
| Dexamine spinosa | | | | | | | | | | | | | + |
| Gammarus | | | | | | | | | | | | | + |
| Paratylus swammerdami | | | | | | | | | | | | | + |
| Perioculodes longimanus | | | | | | | | | | | | | + |
| Asterope mariæ | | | | | | | | | | | | | + |
| Philomedes interpuncta | | | | | | | | | | | | | + |
| Podon intermedium | + | + | + | | | | | | | | + | | + |

**September.**—*Continued.*

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Reel Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Laxey Bay. | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evadne nordmanni | | | | | | | | | | | | | + | |
| Calanus helgolandicus | + | | | | | | | | | | + | | + | |
| Pseudocalanus elongatus | | | | | | | | | | | + | | + | |
| Paracalanus parvus | | | | + | | + | | | | | + | | + | |
| Temora longicornis | + | + | + | + | | + | | | | | + | | + | |
| Metridia lucens | | | | | | | | | | | | | + | |
| Candacia armata | | | | | | | | | | | + | | + | |
| Metropages hamatus | + | + | + | + | + | + | | | | | + | | + | |
| Metropages typicus | | | | | | | | | | | + | | | |
| Paramalocera pattersoni | | | | | + | | | | | | + | | + | |
| Acartia wollastoni | | + | + | | | | | | | | | | + | |
| Diaptomus brevicornis | | | | | | | | | | | | | + | |
| Anomalocera clavipes | | | | | | | | | | | + | | + | |
| Centropages hamatus | + | + | + | + | + | + | | | | | + | | + | |
| Centropages typicus | | + | | | | | | | | | + | | + | |
| Corycæus anglicus | | + | | | | | | | | | | | + | |
| Oithona nana | | | | | | | | | | | | | + | |
| Oithona similis | | + | | | | | | | | | | | + | |
| Microsetella norvegica | | | | | | | | | | | | | + | |
| Harpacticus chelifer | | | | | | | | | | | | | + | |
| Euterpina acutifrons | | + | | | | | | | | | | | + | |
| Euterpina acutifrons | | | | | | | | | | | | | + | |
| Clausocalanus arcuicornis | | | | | | | | | | | | | + | |
| Clausocalanus arcuicornis | | | | | | | | | | | | | + | |
| Oncæa media | | | | | | | | | | | | | + | |
| Oncæa media | | | | | | | | | | | | | + | |
| Oncæa conifera | | | | | | | | | | | | | + | |
| Oncæa conifera | | | | | | | | | | | | | + | |
| Oncæa venusta | | | | | | | | | | | | | + | |
| Oncæa venusta | | | | | | | | | | | | | + | |
| Copepod nauplii | | + | | | | | | | | | | | + | |
| Cirripede nauplii | | | | | | | | | | | | | | |
| Cypris stage of barnacles | + | + | + | | | | | | | | | | | |
| Zoea larvæ | + | + | + | + | | | | | | | + | | + | |
| Decapod eggs | | | | | | + | | | | | | | + | |
| Young Gasteropods | | | | | | + | | | | | | | + | |
| Young Lamellibranchs | | | | | | | | | | | | | + | |
| Fish eggs | | | | + | | | | | | | | | + | |
| Fish larvæ | | | | + | | | | | | | + | | | |
| | 27 | 32 | 26 | 27 | 9 | 14 | — | — | — | — | 19 | — | 58 | — |

## October.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Reed Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Laxey Bay. | Lune Deep. | Port Erin. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bellerochoe malleus | + | | | + | | | | | | | | | |
| Biddulphia mobiliensis | | | | + | | | | | | | | | + |
| Biddulphia aurita | | | | + | | | | | | | | | |
| Chætoceros contortum | | | | | | | | | | | | | + |
| Chætoceros decipiens | + | | | + | | | | | | | | | + |
| Chætoceros teres | | | | | | | | | | | | | + |
| Coscinodiscus concinnus | + | | | + | | | | | | | | | + |
| Coscinodiscus grani | + | | | + | | | | | | | | | |
| Rhizosolenia semispina | + | | | + | | | | | | | | | + |
| Rhizosolenia setigera | + | | | + | | | | | | | | | |
| Rhizosolenia shrubsolei | + | | | + | | | | | | | | | + |
| Ceratium fusus | + | | | + | | | | | | | | | + |
| Ceratium furca | + | | | + | | | | | | | | | |
| Ceratium tripos | + | | | + | | | | | | | | | + |
| Trochiscia brachiolata | + | | | | | | | | | | | | |
| Tintinnopsis campanula | | | | | | | | | | | | | + |
| Noctiluca miliaris | + | | | + | | + | | | | | | | |
| Pleurobrachia pileus | | | | + | | | | | | | | | |
| Medusoid gonophores | + | | | | | + | | | | | | | + |
| Echinoderm larvæ | | | | + | | | | | | | | | + |
| Sagitta bipunctata | + | | | + | | + | | | | | | | + |
| Autolytus prolifer | | | | | | | | | | | | | + |
| Tomopteris onisciformis | | | | + | | | | | | | | | + |
| Larval Polychæta | | | | | | | | | | | | | + |
| "Mitraria" | + | | | + | | + | | | | | | | |
| Crab zoea | | | | + | | + | | | | | | | |
| Crab megalopa | | | | | | + | | | | | | | |
| Mysis stage of Crangon | | | | + | | | | | | | | | |
| Mysis | | | | | | | | | | | | | |
| Eurydice spinigera | | | | | | + | | | | | | | |
| Podon intermedium | | | | | | + | | | | | | | + |
| Evadne nordmanni | | | | | | + | | | | | | | |
| Calanus helgolandicus | | | | + | | | | | | | | | + |
| Pseudocalanus elongatus | | | | | | | | | | | | | + |
| Paracalanus parvus | + | | | + | | + | | | | | | | + |
| Temora longicornis | + | | | + | | + | | | | | | | + |
| Centropages hamatus | + | | | + | | + | | | | | | | |
| Anomalocera pattersoni | + | | | + | | | | | | | | | |
| Labidocera wollastoni | | | | | | + | | | | | | | |
| Pontella lobiancoi | | | | | | + | | | | | | | |
| Acartia clausi | + | | | + | | + | | | | | | | + |
| Acartia discaudata | | | | | | + | | | | | | | |
| Oithona similis | + | | | + | | | | | | | | | + |
| Oithona nana | + | | | + | | | | | | | | | |
| Copepod nauplii | + | | | + | | | | | | | | | + |
| Oikopleura | | | | + | | + | | | | | | | + |
| Ascidian eggs | | | | | | | | | | | | | + |
| Young Gasteropods | | | | | | + | | | | | | | + |
| Young Lamellibranchs | | | | | | | | | | | | | + |
| | 23 | — | — | 30 | — | 18 | — | — | — | — | — | — | 28 |

## November.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Laxey Bay | Lune Deep. | Port Erin. | Luce Bay. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ella bleakleyi | | + | | | | + | | | + | | + | | | |
| ıia mobiliensis | | | | | | + | | | + | | + | | + | |
| ros constrictum | | | | | | | | | + | | + | | | |
| ros debile | | | | | | | | | + | | + | | | |
| ros decipiens | | | | | | | | | + | | + | | + | |
| ros teres | | | | | | | | | + | | + | | | |
| iscus concinnus | | + | | + | | + | | | + | | + | | + | |
| iscus grani | | + | | + | | | | | | | | | | |
| brightwelli | | | | | | | | | + | | + | | | |
| a zoodiacus | | | | | | | | | + | | + | | | |
| borreri | | | | | | | | | + | | + | | | |
| enia semispina | | | | | | + | | | + | | + | | + | |
| enia setigera | | | | | | | | | | | | | | |
| enia shrubsolei | | + | | + | | + | | | + | | + | | + | |
| furca | | | | + | | | | | + | | + | | | |
| fusus | | + | | + | | + | | | + | | + | | + | |
| tripos | | + | | + | | | | | + | | + | | + | |
| psis campanula | | | | | | | | | + | | | | + | |
| a miliaris | | + | | + | | | | | + | | + | | | |
| achia pileus | | | | | | + | | | + | | | | + | |
| l gonophores | | + | | | | | | | | | | | | |
| ipunctata | | + | | + | | + | | | + | | + | | + | |
| s prolifer | | | | | | | | | | | | | + | |
| ris oniseiformis | | | | | | + | | | | | | | | |
| olychæta | | | | | | | | | + | | + | | + | |
| a ,, | | | | | | + | | | + | | + | | | |
| a | | | | + | | | | | | | | | + | |
| galopa | | + | | + | | | | | | | | | | |
| ge of Crangon | | | | | | + | | | | | | | | |
| | | | | + | | | | | | | | | | |
| arina | | | | | | + | | | | | | | | |
| galba | | | | | | + | | | | | | | | |
| elgolandicus | | | | + | | + | | | + | | + | | + | |
| lanus elongatus | | | | | | + | | | + | | + | | + | |
| nus parvus | | + | | + | | + | | | + | | + | | + | |
| ongicornis | | + | | + | | + | | | + | | | | + | |
| ges hamatus | | + | | + | | + | | | | | | | | |
| ra wollastoni | | | | | | + | | | | | | | | |
| lausi | | + | | + | | + | | | + | | + | | + | |
| similis | | + | | | | + | | | + | | + | | + | |
| apax | | | | | | + | | | | | | | | |
| nauplii | | | | | | | | | + | | + | | + | |
| ra | | | | | | + | | | + | | | | + | |
| eggs | | | | | | | | | | | | | + | |
| æ | | | | | | + | | | | | | | | |
| | — | 15 | — | 16 | — | 24 | — | — | 29 | — | 25 | — | 22 | — |

## December.

| | Blackpool. | Ribble Estuary. | Mersey Estuary. | Rhyl to Red Wharf Bay. | Carnarvon Bay. | Cardigan Bay. | Fishguard Bay. | Off Shore Stn. No. 1. | Off Shore Stn. No. 2. | Off Shore Stn. No. 3. | Laxey Bay | Luce Deep. | Port Erin. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coscinodiscus concinnus ... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Ceratium fusus ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Sagitta bipunctata ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| "Mitraria" ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Calanus helgolandicus ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Pseudocalanus elongatus | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Paracalanus parvus ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Temora longicornis ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Centropages hamatus ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Anomalocera pattersoni ... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Acartia clausi..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Copepod nauplii ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... |
| Fish larvæ ..... | ..... | ..... | ..... | ..... | ..... | + | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | — | — | — | — | — | 9 | — | — | — | 9 | — | — | — |

## Occurrence of Pelagic Fish Eggs.

The following table shows the distribution, month by month, in four divisions of the Irish Sea, of the species named during 1906:—

### In Territorial Waters from Blackpool to Red Wharf Bay.

| Months. | Plaice. | Dab. | Flounder. | Brill. | Turbot. | Norway Top Knot. | Lemon Sole. | Long Rough Dab. | Solenette. | Variegated Sole. | Scald Fish. | Cod. | Haddock. | Whiting. | Bib. | Coal Fish. | Ling. | Rockling. | Gurnard. | Common Dragonet. | Spotted Dragonet. | Weever. | Sprat. | Anchovy. | Mackerel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| February..... | + | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| March ..... | + | ... | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | + | .. | ... | ... | ... | ... | ... | ... |
| April ..... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| May..... | ... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | ... | + | ... | ... |
| June ..... | ... | ... | ... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + |
| July.. ..... | ... | ... | ... | ... | ... | + | ... | ... | .. | .. | ... | ... | ... | ... | ... | .. | ... | + | ... | ... | ... | + | ... | ... | ... |
| August..... | .. | ... | ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | + | ... | ... | ... |
| September... | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |

### In Cardigan Bay.

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January..... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |
| February..... | + | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | + | .. | + | ... | + | ... | ... | ... | ... | ... |
| March ..... | + | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | + | + | + | ... | + | ... | ... | ... | ... | ... | ... | ... |
| April..... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | + | ... | ... | + | ... | + | ... | ... |
| May..... | + | + | ... | + | ... | ... | ... | ... | + | + | ... | ... | + | + | ... | ... | + | + | + | ... | + | ... | + | ... | ... |
| June ..... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | + | + | ... | ... | + | ... | + | + |
| July..... | ... | ... | ... | + | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | + | ... | ... | ... | + | + | ... | + |
| August..... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |

## On Off-shore Grounds, N.W. of Piel to Liverpool N.W. Light Ship.

| Months. | Plaice. | Dab. | Flounder. | Brill. | Turbot. | Norway Top Knot. | Lemon Sole. | Long Rough Dab. | Solenette. | Variegated Sole. | Scald Fish. | Cod. | Haddock. | Whiting. | Bib. | Coal Fish. | Ling. | Rockling. | Gurnard. | Common Dragonet. | Spotted Dragonet. | Weever. | Sprat. | Anchovy. | Mackerel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January..... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| February..... | + | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | + | + | .. | + | ... | ... | ... | ... | ... | ... | ... | ... | .. | .. |
| March ..... | + | + | + | ... | ... | ... | ... | ... | ... | ... | ... | + | + | + | + | ... | ... | + | ... | ... | .. | ... | ... | ... | ... |
| April ..... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... | ... | + | ... | ... | + | ... | ... |
| May..... | ... | + | ... | ... | .. | ... | ... | ... | ... | + | + | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | + | ... | ... | ... |
| June ..... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |
| July..... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | + | ... | ... | ... |

## In Vicinity of Port Erin.

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| February..... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |
| March ..... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + | ... | + | ... | ... | . | ... | ... |
| April ..... | ... | .. | ... | ... | ... | ... | ... | + | + | ... | ... | ... | ... | + | ... | ... | + | + | + | + | ... | ... | + | .. | ... |
| May..... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | ... | ... | + | ... | ... | ... | ... | + | ... | + | ... | ... | + | ... | ... |
| June ..... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| July ..... | ... | ... | ... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | + | ... | + | ... | ... |
| August..... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | + | ... | ... | ... | + | + | ... | + |
| September ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | + | ... | ... | ... | + | + | ... | ... |

# FAUNISTIC NOTES.

By Andrew Scott.

**Young Fishes,** *Leptocephalus morrisii*—Plate V.

A perfect specimen of the tape worm form of the *Leptocephalus* stage of the conger eel was found by a local fisherman on April 30th, 1906. The fish was discovered in a small pool of water, left by the receding tide, on the shore, on the east side of Foulney Island. The Leptocephalus was living when captured, but as the fisherman had no means of keeping it alive it soon died. The man handed the specimen over to me soon after he got it. It was then fresh and perfectly transparent, quite soft and flexible. It was so transparent that ordinary print could be easily read through it when placed on a piece of newspaper. In extreme length it measured 118 mm. The weight of the fish after removing the superfluous water was 1·2 grammes, and its volume 1·5 cubic centimetres. The greatest dorso-ventral height of the body was 9 mm., and it was broadest about 65 mm. from the tip of the snout. The myotomes were fairly distinct, and 151 were counted. The fish was colourless, with the exception of a row of black specks along each side of the ventral margin of the anterior half. There was also a similar row of specks along the lateral line, beginning near the greatest height and extending to the tail. The black specks appeared to be placed at the junction of the myotomes, and were very crowded towards the tail. The presence of this rare form so far inshore is apparently unusual. The specimen captured was probably only a wandering individual, as no more have been seen. The figure is from a photograph, and represents the natural size of the fish.

Amongst the other young fishes found in the tow-nettings we have to record the occurrence of **post-larval herrings**. On January 23rd, 1906, a large number were found in a surface tow-netting taken off the Patches Buoy, Cardigan Bay, and also on the same day, off Llanon. A surface tow-netting taken in the vicinity of the Bahama Light Ship, on February 20th, contained one specimen, another tow-netting from Conway Bay, on March 5th, contained three. The majority of these young fish measured 15 mm. in length, one or two 25 mm., and one 35 mm. The other young fishes have already been dealt with.

**Fish Eggs.**—A table showing the distribution from month to month is given above. The first occurrence of plaice eggs during 1906 was in tow-nettings from the Patches Buoy, off Llanon, in Cardigan Bay, on January 23rd. They were again obtained from near the Liverpool North-west Light Ship, on January 31st. From the latter date onwards to the end of March, plaice eggs were tolerably common in many of the tow-nettings taken in the open sea, and in territorial waters. The eggs of the Anchovy were found in tow-nettings taken off Aberdovey, on June 14th, and July 23rd. This is only the second time we have met with Anchovy eggs during a period of ten years. Their occurrence in British seas was first noticed by the late R. L. Ascroft in 1896. The eggs were taken in a surface tow-netting from off Lytham Pier, and identified by Professor McIntosh. The following fish eggs taken in 1906 have not previously been observed in the plankton of the Irish sea. Long Rough Dab: One specimen of the characteristic eggs of this fish was taken at Port Erin, on April 9th. The egg of the Long Rough Dab is about the same size as the plaice egg, but is easily recognised by the large size of the

space between the egg capsule and the yolk. Variegated Sole: A few specimens were found in a tow-netting from the vicinity of Nelson Buoy, at the entrance to the Ribble, on May 31st, and in another from Lune Deep, about five miles south of Piel Gas Buoy, on May 14th. Ling: The eggs of this fish were taken off Port Erin on April 9th, and off New Quay Head on May 1st. Mackerel: Large numbers of eggs belonging to this fish were found in the plankton samples from various parts of Cardigan Bay in June and July, off the entrance to the Ribble in the latter half of June, along the North Wales coast about the same time, and in the vicinity of Port Erin on August 27th. A very extensive incursion of adult mackerel took place during 1906. The fish were caught in various parts of the Irish Sea, between New Quay and the Duddon, from the beginning of June right on to the end of September. Two species of ecto-parasites of fishes were taken for the first time in the Irish Sea in 1906.

**Caligus zei,** Norman and T. Scott. Plate I.

Several specimens of this species were found attached to the skin of a "John Dory" captured in the trawl of the "John Fell," while fishing off New Quay Head, on June 16th. The only other known specimens of this species are in Dr. Norman's collection, and were taken on a "John Dory" captured off the coast of Cornwall forty years ago. The female represented by the drawing on the plate measured 6 mm. in length.

**Lernæenicus encrasicoli** (Turton). Plate II, figs. 6-9.

A large catch of sprats were taken off Blackpool on February 19th, by the fisheries steamer, and a few hundred of these fish were landed at Piel. A careful examination of the fish was made, and one sprat with

two of the above-mentioned parasites attached to it, and another with one, were found. The parasites were embedded in the tissues at the anterior end of the dorsal fin. On dissecting one out it was found that the head had penetrated to the visceral cavity. Fig. 6 represents the natural size of the sprat and its parasite, and also shows the position of attachment. Fig. 7 represents a dissection showing the head of the parasite passing into the visceral cavity. Figs. 8 and 9 represent two views of the head and illustrate the difference between *L. encrasicoli* and *L. sprattæ*.

The following ecto-parasites of fishes have been taken within the past few years, but illustrations are now given to show the differences in the appendages.

**Lernæenicus sprattæ** (Sowerby). Plate II, figs. 1-5.

This parasite is not uncommon on the sprats captured along the Lancashire coast. It differs in the manner of attachment to its host from *L. encrasicoli*. All the specimens of *L. sprattæ* that we have seen were attached to the eye, as shown in the illustration. The barbed head is inside the eye, and the parasite apparently feeds on the semifluid matter. The neck of the parasite is corrugated for some distance from the point of its attachment to the body. In *L. encrasicoli* the neck is quite smooth. The lateral projections of the head differs somewhat in the two species. In *L. sprattæ* they are directed backwards, and in *L. encrasicoli* they are nearly at right angles to the head. The appendages in the two species appear to be identical, and consist of one pair of antennules, one pair of antennæ, and four pairs of rudimentary feet. The four pairs of feet have probably remained in the same condition from the free-swimming larval period.

**Lernanthropus kroyeri**, van Beneden. Plate III.

We find this parasite occasionally attached to the gills of Bass (*Labrax lupus*), caught at the entrance to Barrow Channel. When living the animal is a dark red colour, and rather difficult to see. It differs from any of the other ecto-fish parasites with which I am acquainted by the possession of a peculiar appendage situated close to the base of the antennules of both sexes. The appendage is of irregular shape, somewhat pointed towards the apex, and apparently composed of two joints. Its situation and structure are shown by fig. 3 on the plate. The female is about 21·7 mm. in length, inclusive of the thoracic appendages. The male is rather different from the female and is about 10·5 mm. long. It apparently lives as a parasite on the female. I have never come across any that were isolated, and living directly on the gills of the fish. The appendages are nearly identical in the two sexes. They consist of one pair of seven-jointed antennules, with secondary processes, one pair of antennæ, one pair of mandibles enclosed in a suctorial tube, one pair of maxillæ, two pairs of maxillipedes, and two pairs of rudimentary feet. The outer branch of the second pair of feet of the male has a slightly different armature from that found on the second pair of the female. The outer branch of the female second foot is armed with four spines, while the male has two small spines and a number of minute teeth at the apex of the branch. The furca are large and conspicuous. The spermatophores frequently found attached to the female are globular in shape, and of a dark brown colour.

**Clavella labracis ?**, van Beneden. Plate IV.

While trawling in Luce Bay for large plaice for the tanks, a few *Crenilabrus melops* were captured amongst

the other fishes. One of these was dissected and a few *Clavella* were found attached to the gill filaments. In general appearance the parasite resembles van Beneden's species which we have already recorded for the Irish Sea from another kind of wrasse. Our first specimens were found on the gills of the Ballan wrasse (*Labrus bergylta*). The present species is a very small one, and is only 1 mm. in length, exclusive of the egg sacs. The species has only one pair of maxillipedes. The antennules are five jointed and armed with short spatulate hairs, the first joint has a short, thick hair placed on the lower margin near the junction with the second joint. The antenna are in the form of very strong slender hooks. The mandibles and maxilla are rudimentary; the former appears to have no serrate apex. There are two pairs of rudimentary feet, both two-branched. The first pair has both branches composed of two joints, while the second pair has a two-jointed outer branch, and a three-jointed inner branch. The furca are very small and inconspicuous. No males were found.

## Explanation of the Plates.

### Plate I.

*Caligus zei*, Norman and T. Scott.—

Fig. 1.—Adult female seen from above. × 11.
„ 2.—Antennule.
„ 3.—Antenna.
„ 4.—Sternal fork.
„ 5.—First maxilliped.
„ 6.—Second maxilliped.
„ 7.—Fourth foot.
„ 8.—Abdomen of male.

### Plate II.

Fig. 1.—*Lernæenicus sprattæ* (Sowerby), in situ. Natural size.
„ 2.—*Lernæenicus sprattæ*, removed from its host. × 2·5.
„ 3.—Head and anterior portion of thorax of *L. sprattæ*. × 5.
„ 4.—Antennule. × 126.
„ 5.—Antenna. × 80.
„ 6.—*Lernæenicus encrasicoli* (Turton), in situ. Natural size.
„ 7.—Dissection showing position of head in the host. × 3.
„ 8.—Head and anterior portion of thorax, from above. × 6.
„ 9.—Head and anterior portion of thorax, from left side. × 6.

## Plate III.

*Lernanthropus kroyeri*, van Beneden.

Fig. 1.—Adult female, seen from above. × 13·4.
„ 2.—Antennule and secondary process. × 120.
„ 3.—Antenna. × 60.
„ 4.—Mandible. × 181.
„ 5.—Maxilla. × 181.
„ 6.—First maxilliped. × 90.
„ 7.—Second maxilliped. × 90.
„ 8.—First foot. × 90.
„ 9.—Second foot. × 90.
„ 10.—Outer branch of second foot, male. × 90.
„ 11.—Abdomen and furca of female, with spermatophores. × 90.
„ 12.—Adult male seen from above. × 13·4.
„ 13.—Abdomen and furca of male. × 90.

## Plate IV.

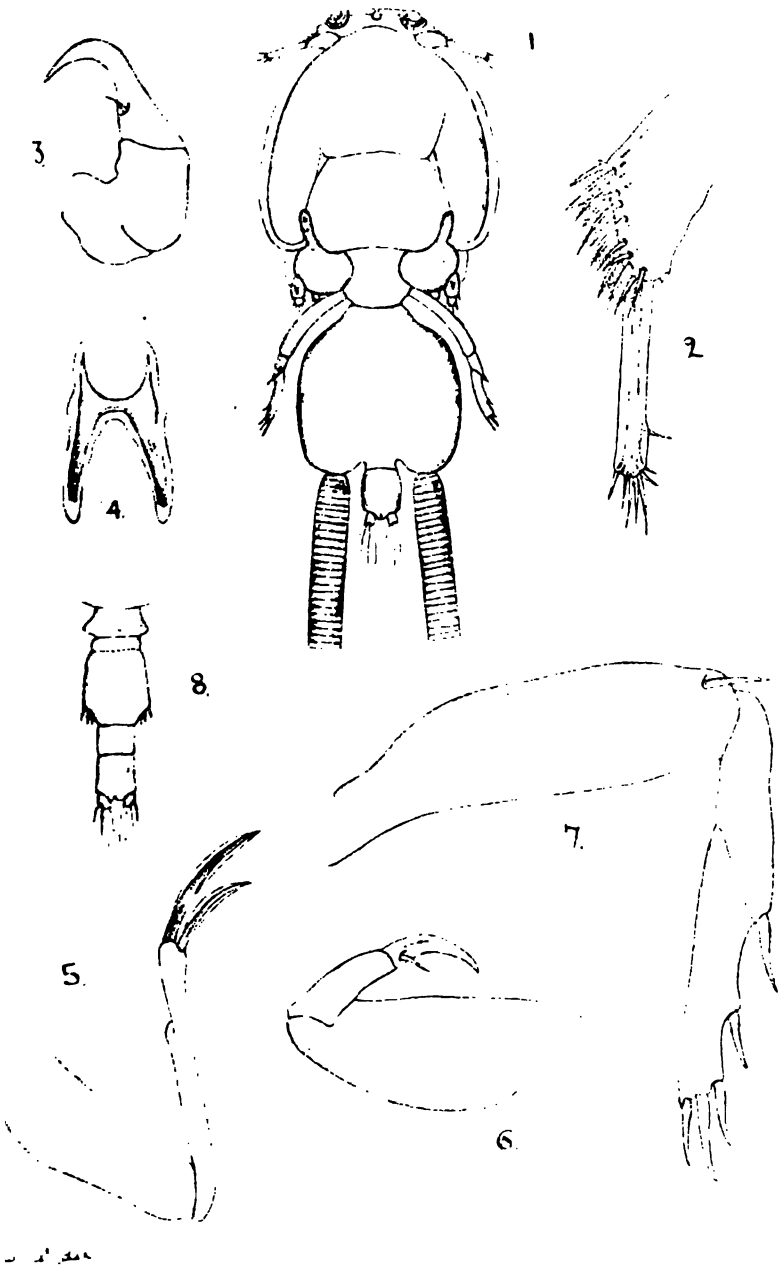
*Clavella labracis*, van Beneden.

Fig. 1.—Adult female seen from above. × 45.
„ 2.—Antennule. × 390.
„ 3.—Antenna. × 390.
„ 4.—Mandible. × 781.
„ 5.—Maxilla. × 781.
„ 6.—Maxilliped. × 390.
„ 7.—First foot. × 390.
„ 8.—Second foot. × 390.
„ 9.—Abdomen and furca. × 390.

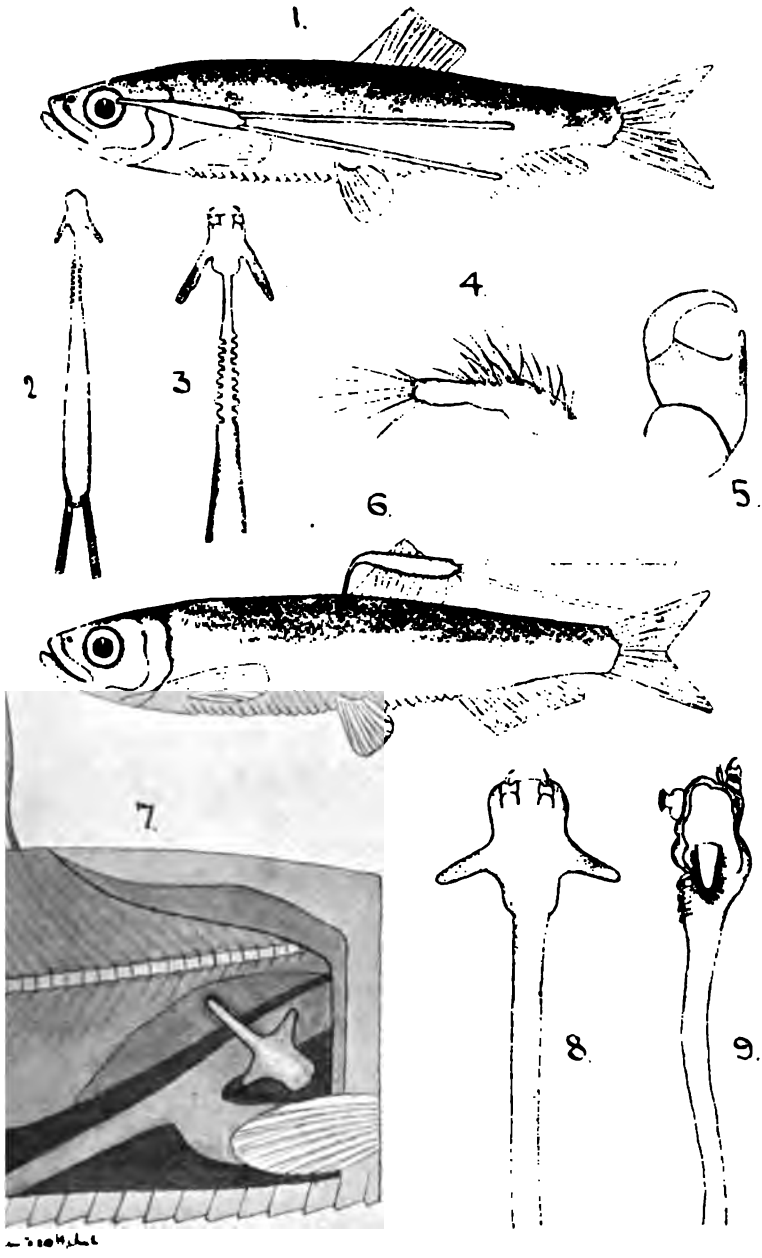
## Plate V.

*Leptocephalus morrisii*

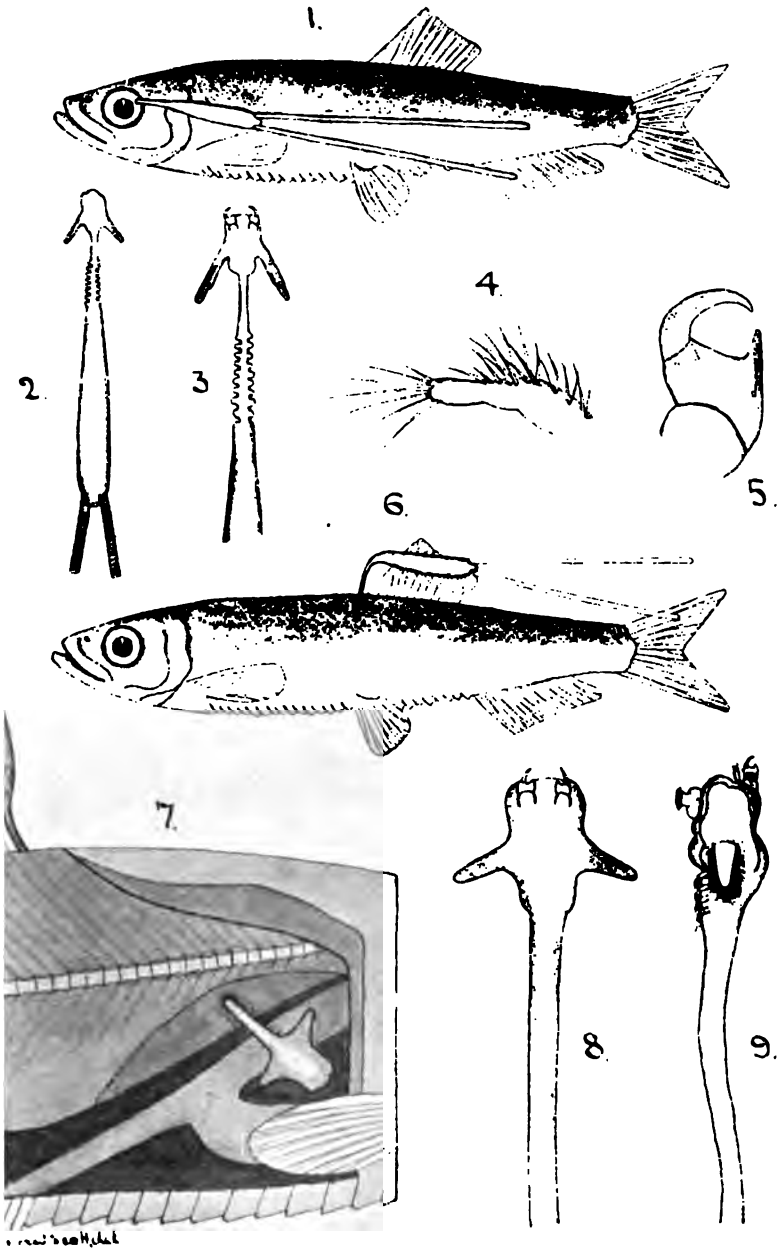
Natural size, and seen from the right side.



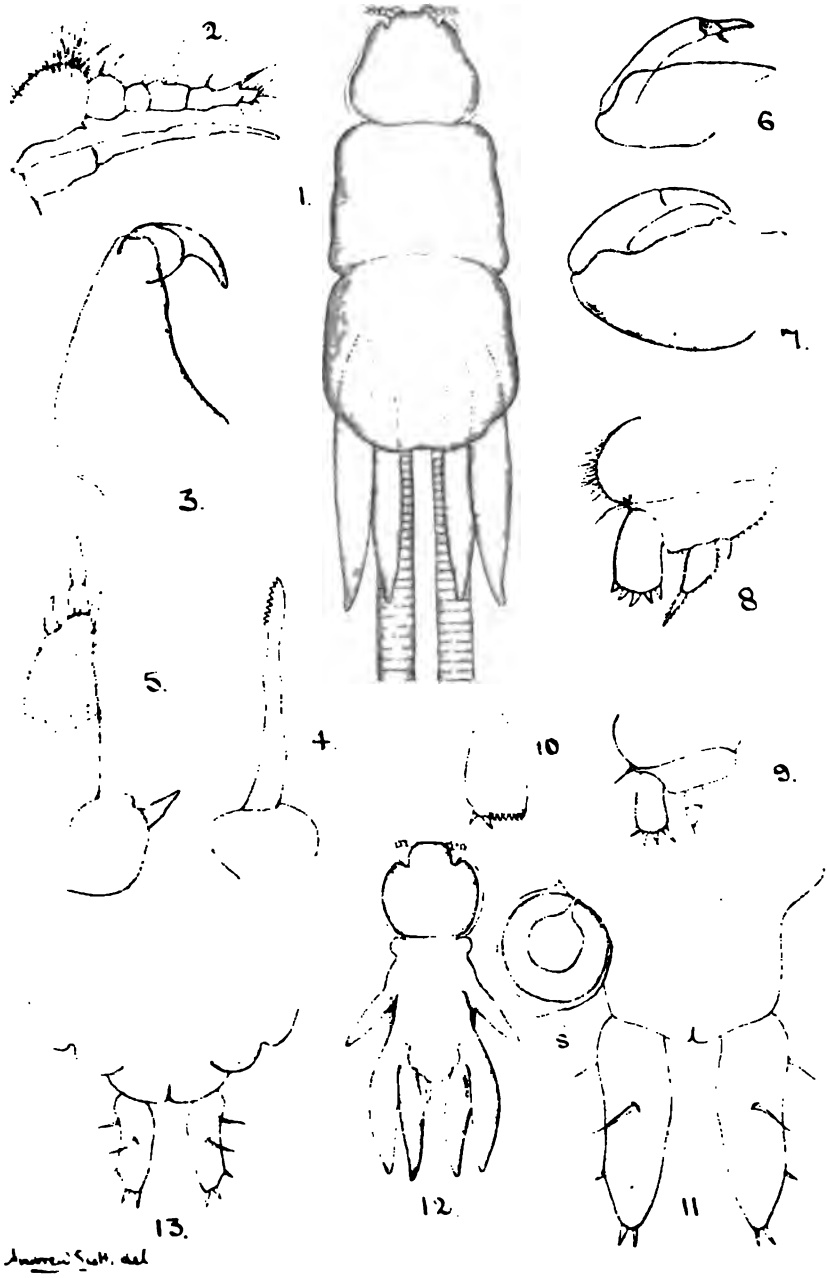

CALIGUS ZEI. Norman and T. Scott.



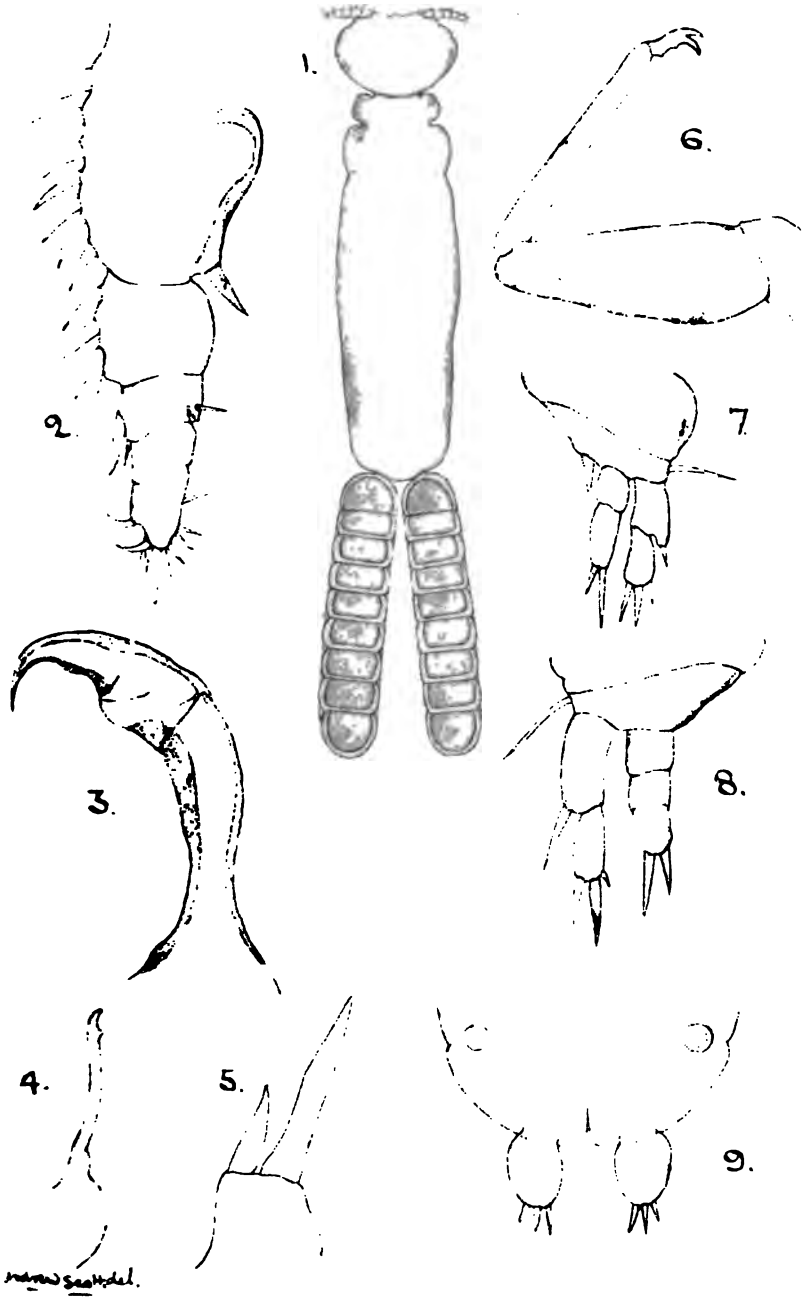

FIGS. 1–5. LERNÆENICUS SPRATTÆ (Sowerby).
FIGS. 6–9. *LERNÆENICUS ENCRASICOLI* (Turton).




FIGS. 1–5. LERNÆENICUS SPRATTÆ (Sowerby).
FIGS. 6–9. LERNÆENICUS ENCRASICOLI (Turton).




LERNANTHROPUS KROYERI, van Beneden.




*CLAVELLA LABRACIS*, van Beneden.

# Plate V.

Leptocephalus stage of Conger Eel. Nat. size.

# NOTES ON THE FOOD OF YOUNG FISHES.

By Andrew Scott.

The tow-nettings taken during the summer months frequently contain the post-larval, and later stages of various kinds of fishes. In some cases identification is tolerably easy. In others, the work of assigning the post larval fishes to any particular species, is sometimes an impossibility. These tender objects are very easily mutilated in capture. In all cases, even when the young fishes cannot be identified with certainty, the stomach and intestines are now being examined to find out what the fish has been feeding on. The internal organs owing to the size of the fish, are naturally small, and cannot be examined in the ordinary way. The methods adopted in this work which give fairly satisfactory results are, (1) removing the entire alimentary system with the aid of a low power dissecting microscope, then carefully dissecting the stomach under a Zeiss A, or Leitz No. 3 objective, a cover glass is next put on, and the whole contents carefully gone over; (2) dehydrating, clearing, and mounting the stomach, or even the whole fish, in the ordinary way for a permanent preparation in Canada balsam. The former method has the advantage that little time is taken up in the work. The latter one may take a few hours, and the results do not always repay the labour involved. As a rule, the shorter method is now employed. All the young fishes examined were caught by an ordinary open tow-net, worked just under the surface of the sea. The following are the fishes that have been examined, with the locality of capture, size in millimetres, and food found.

## Post-larval Cottus.

| Locality. | Millimetres. | Food. | Remarks. |
|---|---|---|---|
| 1 Near Duddon Bar. 20.3.06. | 9 | 3 *Temora longicornis.* 1 *Oithona similis.* | *Temora* rare and *Oithona* absent in plankton. |
| 1 off Llanbedrog, Cardigan Bay, 27.4.06. | 8 | 2 *Acartia clausi.* | *Acartia* tolerably common in tow-net. |

## Post-larval Gurnard.

| | | | |
|---|---|---|---|
| 1 Red Wharf Bay, 15.6.06. | 8 | No food in alimentary canal. | — |

## Post-larval Weever.

| | | | |
|---|---|---|---|
| 1 off Kilan Head, Cardigan. | 5 | 1 *Paracalanus parvus.* | *Paracalanus* not present in the plankton. |
| 1 ,, 12.7.06. | 5 | 3 ,, | |
| 1 Red Wharf Bay, 7.9.06. | 12 | 1 *Temora longicornis.* 12 *Paracalanus parvus.* 14 *Isias clavipes.* | *Paracalanus* only present in the plankton. |

## Post-larval Gadoids.

| | | | |
|---|---|---|---|
| 1 Twenty-one miles N.W. of Piel, 20.3.06. | 4 | 2 *Oithona similis.* | Absent from the plankton. |
| 1 Five miles W. of Morecambe Bay Light-Ship, 7.5.06. | 14 | 3 *Temora longicornis.* 1 *Anomalocera pattersoni.* | *Temora* only present in the plankton. |
| 1 off New Quay Head, Cardigan, 25.5.06. | 20 | 3 *Centropages hamatus.* 1 *Oithona similis* | *Centropages* only present in the plankton. |

## Post-larval Rockling.

| | | | |
|---|---|---|---|
| 6 off Dinas Head, 15.6.06. | 14 | No food. | — |
| 2 off New Quay Head, 10.7.06. | 14 | No food. | — |
| 7 off Morecambe Bay Light-Ship, 21.7.06. | 16 | No food. | — |
| 1 off New Quay Head, 16.7.06. | 18 | 10 *Acartia clausi.* 2 *Temora longicornis.* | *Acartia* tolerably common in the plankton, *Temora absent.* |

| Locality. | Millimetres. | Food. | Remarks. |
|---|---|---|---|
| 1 off Entrance to Ribble, 18.7.06. | 25 | 3 Larval barnacles (Cypris stage).<br>2 *Anomalocera pattersoni* | No larval barnacles in the plankton, *Anomalocera* scarce. |
| 1 off New Quay Head, 19.7.06. | 25 | 1 Larval barnacle (Cypris stage).<br>1 *Anomalocera pattersoni.* | No larval barnacles in the plankton, *Anomalocera* scarce. |
| 1 off Kilan Head, 22.7.06. | 30 | 4 Crab megalopa. | Crab megalopa very plentiful in the plankton. |
| 1 Carnarvon Bay, 20.7.06 | 32 | 7 Crab megalopa. | Megalopa scarce in the plankton. |
| 1 Red Wharf Bay, 7.8.06. | 33 | 1 Crab megalopa. | Megalopa scarce in the plankton. |
| **POST-LARVAL BELONE.** | | | |
| 1 off New Quay Head, 10.7.06. | 20 | 1 *Acartia clausi.*<br>2 *Ectinosoma normani.* | *Acartia* tolerably common in the plankton. |
| 1 off Niarbyl, 30.7.06 | 22 | 1 *Acartia clausi.* | *Acartia* scarce in the plankton. |
| **POST-LARVAL SAND EELS.** | | | |
| 55 from various parts of the territorial area | 10-17 | No food. | — |
| **POST-LARVAL PLAICE.** | | | |
| 1 Tremadoc Bay, 19.2.06. | 15 | No food. | — |
| **POST-LARVAL DABS** | | | |
| 9 Aberporth Bay, 16.5.06. | 11 | No food. | — |
| 9 Fishguard Bay, 24.5.06. | 11 | No food. | — |
| **POST-LARVAL SOLES.** | | | |
| 1 off New Quay Head, 15.6.06. | 6 | No food. | — |
| 1 off Puffin Island 28.6.06. | 7·5 | 1 *Longipedia minor.*<br>1 *Ectinosoma sarsi.*<br>6 ,, *normani.* | Littoral Copepoda. |

POST-LARVAL SPRATS.

| Locality. | Millimetres. | Food. | Remarks. |
|---|---|---|---|
| 1 off New Quay Head, 10.7.06. | 15 | 2 *Pseudocalanus elongatus.* | *Pseudocalanus* not present in the plankton. |
| 1 off Blackpool, 18.7.06. | 15 | 1 *Pseudocalanus elongatus.* | *Pseudocalanus* not present in the plankton. |
| 1 off Port Erin, 20.7.06. | 16 | No food. | — |

YOUNG PIPE FISH.

| | | | |
|---|---|---|---|
| 1 Red Wharf Bay, 7.9.06 | 66 | 2 *Pseudocalanus elongatus.*<br>2 *Paracalanus parvus.*<br>6 *Acartia clausi.* | No *Pseudocalanus* in the plankton, *Paracalanus* and *Acartia* tolerably common. |

The food, in all the cases where it could be recognised, consisted of crustacea, chiefly copepoda. The group was represented mainly by the pelagic forms. The few littoral representatives found indicate that the fishes containing them had been feeding near the bottom of the sea previous to capture. It evidently does not follow that if a particular copepod is any way numerous, the fish feeds entirely upon it. In the above results it will be noted that there are several instances where the fish stomachs contained copepoda not represented in the surrounding plankton taken in the tow-net along with the young fish. The fish, no doubt, in its movements through the water encounters various kinds of copepods. It is not known, however, whether it feeds indiscriminately on every one, or selects particularly coloured forms. The majority of the copepoda are more or less coloured, and so may be quite conspicuous apart from their size. It is probable that the difference between the copepods in the plankton and those in the fish stomach is due to the unequal distribution. The fish may meet with a small shoal of *Anomalocera*, young barnacles, or crab larvae, capture a few of them, and pass on. It may then reach

nts of the stomach and intestine of a Flounder. Nat. size.

PLATE VII.

Contents of the stomach and intestine of a Plaice. Nat. size.

a part of the surface waters where the copepoda are quite different from its previous meal, and begin to feed again. In this way one would get a selection of copepods which might or might not be represented in the area tow-netted.

The following photographs show the food found in the stomachs of two of the marked fishes, when re-captured.

One is a flounder (LL86) caught on Baicliff sands, on May 26th, 1906. The food consisted mainly of *Tellina balthica*, with a few cockles, and two *Hydrobia ulvæ*. The fish weighed 272 grammes. The clean dried shells weighed 11·82 grammes (see Plate VI.).

The other is a plaice (LL78) caught on Baicliff sands on June 2nd, 1906. In this case the food consisted of cockles only. The fish weighed 221 grammes, and the clean dried shells 11·5 grammes (see Plate VII.).

Besides those illustrated we have noted the following:—LL117, caught on the Barrow sands on July 3rd, 1906. The food was mainly *Tellina balthica*, with a few *Corophium* (an isopod) and the remains of one small shore crab. LL896, flounder, caught in the Duddon, near Askam, on July 18th, 1906. The food consisted of *Tellina balthica*, and cockles, in equal quantity. A lesser sand eel caught in Ulverston Channel on May 24th, 1906, had four transforming plaice, six *Corophium*, four *Mysis*, and a large number of *Gammarus* in its stomach.

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PLATE VI.

Contents of stomach, etc., of flounder (LL86). Photographed natural size.

PLATE VII.

Contents of stomach, etc., of a plaice (LL78). Photographed natural size.

# ARTIFICIAL FISH-HATCHING IN NORWAY.

By (I) G. M. Dannevig and (II) K. Dahl.

The name of Captain G. M. Dannevig has been associated with the artificial hatching of cod fry in Norway for many years. The utility of the distribution of such fry has been recently criticised by Dr. Hjort and Mr. K. Dahl. I have asked Captain Dannevig and Mr. Dahl to furnish me with brief accounts of recent experiments and observations, each from his own point of view; and I print these below as likely to be of interest to readers in this country.

W. A. Herdman.

## *I.—Letter from Captain G. M. Dannevig.*

"To Prof. W. A. Herdman, F.R.S., &c., &c.

Dear Sir,

The investigations intended to solve the very much disputed question as to the utility of planting artificially-hatched cod fry in our fjords are now concluded, and from my point of view the results are extremely satisfactory.

The facts are as follows:—

The Söndeledfjord was investigated in the latter part of September in the years 1903, 1904 and 1905, and the Hellefjord in the beginning of October in the same years. Cod fry were planted in the Söndeledfjord in the spring, 1904 and 1905, in all about 48 millions; and in the Hellefjord in the spring of 1905, about 8 millions.

The investigations as well as the planting of the fry were controlled by Dr. Hjort's assistant, Mr. K. Dahl.

The Stendalsfjord, to the westward of Lillesand, was investigated by me, and on behalf of the Nedenas County, in the first part of September, 1904, 1905 and 1906, and fry were planted in spring 1905 and 1906, in all about 16 millions. All investigations have been made with the same seine, 22 fathoms long and 4·2 metres deep in the middle. In Sóndeledfjord 106 hauls, in Hellefjord 21 and in Stendalsfjord 34 hauls. The hauls were made in the same places, almost on the same date in the different years, and as uniformly as possible. The numbers given are the entire quantities except where given as the mean of two years.

The results are:—

I.—Before Planting of Fry.

| Place and Year. | Cod. | Whiting. | Pollac and Saithe. |
|---|---|---|---|
| Sõndeledfjord, 1903 ... ... | 426 | 1,309 | 137 |
| Hellefjord, 1903 + 1904 ÷ 2 ... | 85 | 259 | 23 |
| Stendalsfjord, 1904 ... ... | 454 | 99 | 131 |
| Total ... ... ... | 965 | 1,667 | 291 |

II.—After Planting of Fry.

| Place and Year. | Cod. | Whiting. | Pollack and Saithe |
|---|---|---|---|
| Sõndeledfjord, 1904 + 1905 ÷ 2... | 1,328 | 1,150 | 160 |
| Hellefjord, 1905 ... ... | 143 | 180 | 3 |
| Stendalsfjord, 1905 + 1906 ÷ 2... | 855 | 230 | 197 |
| Total ... ... ... | 2,326 | 1,560 | 360 |

All yearlings. Only cod fry planted. Now it is incontestable that the cod have increased. The question

## Total Results of Investigations.

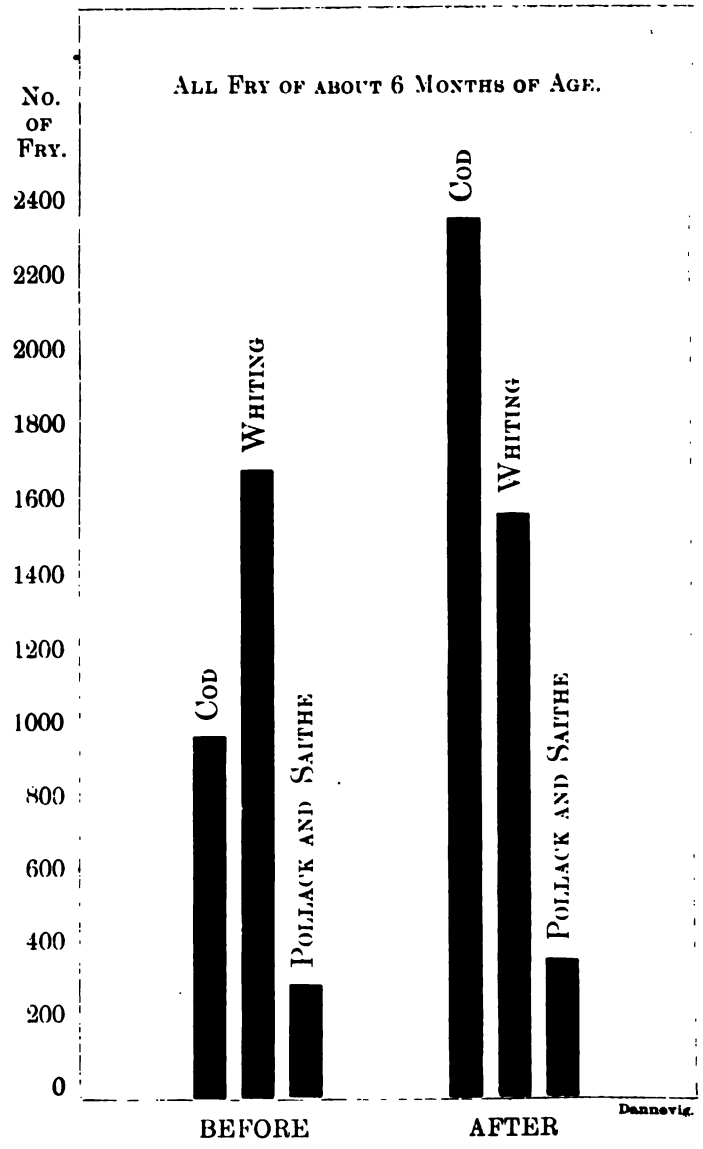



Fig. 2. Planting of Cod Fry.

is: What is the cause of the increase? I will, of course, answer: The planting of the fry. But, not so with Messrs. Hjort and Dahl. They attribute the increase to different sorts of currents, to temperature, salinity, etc., and as you will have seen from the report, Mr. Dahl goes on through one hundred pages to explain these different phenomena and their influence. Well, you will judge for yourself. I shall only add that Dr. Hjort is no friend of fish hatching, but, of course, you know all about that.

In "Report on Norwegian Fishery and Marine Investigations," pages 120-137, Dr. Hjort has put forward a series of hypotheses regarding the fisheries in our fjords, which I was bold enough to dispute, and the investigations have shown that I was right on every point.

1. It is proved that there is a great number of cod (yearlings and larger) in the fjords during the whole summer.

2. The eggs and fry don't float on the surface, but in the deeper and salter layers.

3. The surface current can't bring the eggs out of the fjords, as it only contains very few, as a rule none, of them.

4. The "local tribes" (page 135) do exist, and the proof is, that, according to Dahl, the spawning cod in the fjord have a mean length of 33 cm., while in the North Sea the spawners, according to Hjort, have a length from 55 cm. and upwards. All this, and much more, is proved by Mr. Dahl himself.

The intention of the Storthing in granting funds for the work was to find out whether the number of yearlings had increased after planting of fry from Flödevigen. My proposal that the investigations should be carried out in September, when the yearling cod was large enough to be caught in a common seine, made of netting with small

meshes, was adopted by the Storthing as well as by Dr. Hjort. This gentleman, however, thought that the manner proposed was not detailed enough to give a reliable result, and ordered Mr. K. Dahl to undertake a series of contemporary investigations regarding the currents, &c., in the Fjords. Consequently we have two different reports—one from Mr. Dahl concerning his own work, of which I know nothing, and one from me relating to our joint investigations.

The results arrived at are contrary to one another. Mr. Dahl calculates the currents, and concludes that the fry must have been carried out to sea. I have proved that the fry are in the Fjords, and Mr. Dahl has handled and measured everyone of those caught; but of this he says nothing. Mr. Swenander, who has been conducting investigations in the Trondhjemsfjord for three years, has arrived at conclusions entirely different from those of Dahl.

Dr. Hjort agrees with Mr. Dahl. He admitted, however, at the last meeting of the Fiskeriraad, that he had greatly altered his views during the last eight years, "and that he had found that he then did not know so much about fishery matters as he thought he did," but he did not say on what points his opinion was altered.

Yours truly,

G. M. Dannevig."

## *II.—Investigations concerning the effects of liberating artificially hatched Cod Larvae in the Fiords of Southern Norway.*

By Knut Dahl.

At the request of Professor Herdman I intend, in the following pages, to give a short account of the special investigations undertaken in this country in order to understand the conditions under which we are adding hatched pelagic cod larvae to Norwegian fiords. A more detailed account has been published in Norwegian, and will probably appear later in English or German. I will here only state a few main results.

The investigations were carried out in some of the small fiords of the Skagerrak, and also on the coast and in the "Skiaergaard" outside the fiords. Captain Dannevig and I undertook, upon a plan made by him, a series of investigations in the fiords: Söndeledfiord, near Risör, and Hellefiord, near Kragerö (see Chart, fig. 3).

In these fiords the occurrence of cod fry (of the year) in the bottom stage (littoral fry) was investigated by means of a large series of hauls with a small seine (101-106 hauls in the Söndeledfiord, and 21-27 hauls in the Hellefiord). These hauls were made, as far as possible, in the same places and in the same manner. They were first made in September-October, 1903, and repeated in July-August, 1904, September-October, 1904, July-August, 1905, and September-October, 1905. The seine was 22 fathoms long, 4·20 metres deep in the middle. The mesh was about 18 meshes per foot (Norw.) on the wings of the seine. In the middle part of the seine

there was a piece, $7\frac{1}{2}$ fathoms long of a mesh of 21 meshes per foot (Norw.). In July-August a piece of "Congrès" (strong open) cloth 5·5 metres long and as deep as the seine was inserted in the middle.

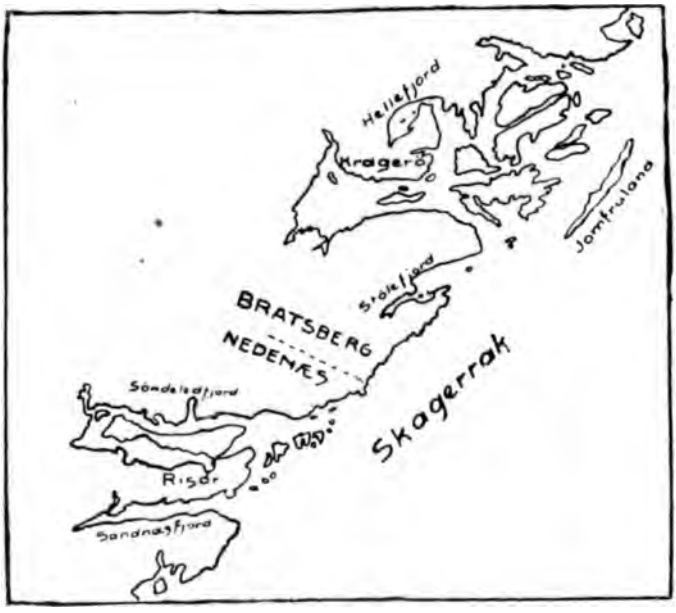



Fig. 8. General map of four fiords examined.

The fiords in question are deep fiords and the littoral fry mainly live on the relatively small shelves along the shore, in the zostera region, where the hauls with the seine were made. In 1904 about 33·5 millions of cod larvae were brought from the Flödevigen hatchery to the interior of Söndeledfiord. In 1905 33 millions of cod larvae were brought from the hatchery to the Söndeledfiord, and 10 millions to the Hellefiord. The results of the hauls made by Mr. Dannevig and me are as follows:—

| | Söndeled Fiord. | | Helle Fiord. | |
|---|---|---|---|---|
| | Larvae liberated in the spring. | Cod fry per haul. | Larvae liberated in the spring. | Cod fry per haul. |
| Sept.-Oct., 1903 | None | 4·8 | None | 1·9 |
| July-Aug., 1904 | 33·5 millions | 33·7 | None | 10·9 |
| Sept.-Oct., 1904 | | 15·1 | | 6·5 |
| July-Aug., 1905 | 33 millions | 11·4 | 10 millions | 1·5 |
| Sept.-Oct., 1905 | | 11·5 | | 7·5 |

It is obvious that the number of cod fry obtained per haul varies both in the different years, and also in different seasons, independently of hatching operations, to such an extent, that no safe conclusions can be drawn from the above facts alone.

Previous experience in this country had shown similar facts, and from the beginning of the work, the Fishery Board had pointed out the necessity of investigations concerning the natural spawning of the cod, the occurrence of natural larvae, the hydrography of the fiords in question, and finally the occurrence of littoral fry in the neighbouring fiords where no fry had been liberated. By order of the Board I undertook, in the years 1904 and 1905, such investigations apart from my participation in Mr. Dannevig's experiments. The occurrence of littoral cod fry was examined in the neighbouring fiords: Sandnesfiord and Stölefiord (see Chart, fig. 3). The seine employed was 38 metres long. Depth in the middle 4·5 m., in the points 1·75 m. Mesh, 16 meshes per foot (Norw.). A piece of net 5 mm. between the knots, 10·5 m. long, was inserted in the middle of the

seine. The smallest littoral cod fry could always be retained by this seine.

With this seine the Sandnes and the Stöle fiords were examined in July (respectively 10 and 7 hauls), and September-October (respectively 21 and 20 hauls). The hauls were first made in 1904 and repeated in 1905.

In the Kristianiafiord 28 hauls were made in August, 1904 and 1905. All the hauls were made as far as possible in the same places and in the same manner in both years.

The occurrence of spawning cod was studied by collecting statistics from the fishermen. The occurrence of pelagic cod eggs and larvae in the fiords and the Skagerrak was studied by making fortnightly tow-nettings in the following manner. A small motor boat dragged a circular net (1 m. diam.) of silk gauze for five minutes. The net was buoyed up so as to fish within a certain distance of the surface. In this way the net was towed 0, 2, 5, 10, 20 metres distance of the surface. The distance covered by the boat at each tow-netting was, by means of repeated experiments, proved to be about 250 metres. The occurrence of post-larval cod was studied by means of larger nets dragged for hours, and also by hand-nets.

The hydrographical changes in the Sandnesfiord the Sóndeledfiord and the Skagerrak were investigated by means of taking fortnightly traverses of the waters in question. Also direct current measurements were occasionally done with the Ekman current meter, and also with other apparatus.

These investigations have given a series of facts, which in my opinion justify the conclusion *that the adding of artificially hatched cod larvae is incapable of influencing the natural stock of fry, even in very small and limited waters, to a perceptible degree.*

At the beginning of these investigations I considered it important to study the question, whether the natural production of fry was great or insignificant in the localities in question. To this end I have from Risör gathered statistical reports on the quantity of cod caught in the Söndeledfiord.

By comparison of this material with the result of marking experiments (proportion of recaptures to number of marked fish) the conclusion may safely be drawn, that even in a small fiord like the Söndeledfiord tens of thousands of cod spawn every year, while the Flödevigen hatchery yearly manipulates the roe of about 500 cod (males and females) and distributes the hatched larvae over the whole of the Skagerrak coast. The number of spawning cod on this coast is indeed to be counted in millions.

By making uniform hauls with a tow-net (see above) I have endeavoured to study the quantitative occurrence of eggs and larvae of the cod. By these tow-nettings it was found that the eggs of the cod may occur in such numbers in the upper layers of the Söndeledfiord that up to 4,000 cod eggs may be obtained in five minutes' tow-netting. A calculation based upon the supposition that the number of eggs gathered by a series of tow-nettings in the spring, 1904, down to 10 metres in four different stations, represent approximately true values for the whole of the inner fiord, gives very large figures. Indeed, we get figures so great, that we may safely draw the conclusion, that even the interior of the Söndeledfiord an area not exceeding five square kilometres, may in one single day contain more eggs than the Flödevigen hatchery produces in the whole season. And these quantities of eggs, the number of which may be calculated at a certain time in a fiord, are, of course, not the

whole production. Quantities are hatched previously, masses are hatched daily, and new eggs are daily spawned. Also they are distributed by the current over areas where no spawning takes place.

The natural spawning and hatching of cod eggs in the fiord is also of much longer duration than in the hatchery. Even before the fry of the hatchery are ready for planting out I have found multitudes of cod larvae in the fiords and the Skagerrak, and I have proved that cod eggs and recently-hatched cod larvae occur in the waters in limited numbers, even months after the operations at the Flödevigen hatchery have ceased.

The natural spawning and hatching of cod eggs is, therefore, in the small area, which I have investigated round Risör, of far greater dimensions than the production of larvae at Flödevigen a production which is limited to a shorter space of the season, and which is to be distributed over a large stretch of the coast.

In 1905 a series of hauls was made in order to test whether the adding of hatched cod larvae to the Söndeledfiord was capable of influencing the number of occurring larvae. A few days before the first liberation of hatched larvae took place, I made 20 hauls of five minutes' duration in four stations. The net fished on each station within 0, 2, 5, 10 and 20 metres of the surface. These hauls were repeated on three occasions during and after the period of liberation of the hatched fry.

The following tables give the dates, the total catches on each occasion, and the dates of the liberation of the different portions of larvae: —

| Larvae * liberated | |
|---|---|
| Date | Millions |
| 4/4/05 | about 7 |
| 7/4/05 | ,, 8 |
| 10/4/05 | ,, 10 |
| 19/4/05 | ,, 8 |

| 20 Hauls each time | Cod eggs | Cod eggs last stage | Cod larvae | Size of larvae |
|---|---|---|---|---|
| Date | | | | |
| 28/3–29/3/05 | 1840 | 64 | 154 | 3–5 mm |
| 12/4–13/4/05 | 2201 | 76 | 83 | 3·5–5 mm |
| 29/4–2/5/05 | 2134 | 18 | 37 | 3·5–8 mm |
| 15/5–16/5/05 | 1075 | 22 | 44 | 2–10 mm |

It will be observed that the liberation of 33 millions of cod larvae produced no effect which could be recognised in the numbers caught. The totals from the hauls show that eggs were constantly spawned and hatched. *But the relation between eggs and larvae is never influenced in the favour of larvae.* For instance, notwithstanding that more than 20 millions were liberated between the first and second investigations, and that 10 millions were liberated even two days previous to the second investigation, the number of larvae constantly decreased as did the number of eggs in the last stage. On the fourth examination the number of eggs in the last stage as well as of larvae, again slightly increased.

A decrease in the number of larvae is naturally to be expected with the advancing season. But this decrease and the final slight rise is also explained by a consideration of the hydrographical changes which took place at the time of the investigations.

It will easily be understood that these small recently-hatched cod larvae which are liberated in the fiords are freely exposed to the movements of the water. During the many weeks (they rarely appear at the bottom before June-July) in which they are leading a pelagic life in

* Larvae from the Flödevigen hatchery, ready for liberation, measure (preserved in formalin, same as the captured larvae) from 3·5 to 4·5 mm.

the upper water layers, they will be largely dependent on currents. After they have grown larger they also to a very great extent take refuge under jellyfish and follow their drift.

No investigator, wishful of forming an unprejudiced opinion, can justly ignore the possibility that the eggs and young of the cod during this relatively long space of time, while they are leading a pelagic life in the waters of the sea, may, and under certain circumstances undoubtedly *must*, be subject to the movements of the waters and dependent on these as to their fate.

If we should endeavour to propagate the plants of a field with seed which floated in the air for a couple of months, surely we would have to consider the currents of the air. It is thus obvious that an understanding of the hydrographical changes in the fiords and their effects on the larvae is essential for the solution of the problem. The eggs and larvae live, according to my material, chiefly in water between 20 and 30 per thousand salinity; such as the relatively fresh surface water, which covers the salter water of the Skagerrak and fills the upper layers in the Skagerrak fiords. Eggs and larvae are distributed from about 20 metres and upwards in numbers which generally diminish towards the surface, but occur in the different depths in about the same relation to each other. Thus the larvae do not float lower than the eggs.

By experiments undertaken by Mr. Dannevig and me in the Flödevigen hatchery the recently spawned eggs and newly hatched larvae were all found to float at the surface of water of a density (*i.e.*, specific gravity *in situ*) of 1,021 and in water of less density they floated or sank in the same proportion to each other. Direct current measurements have shown that this water-layer which contains the eggs and larvae moves as well in as out of

the fiords. The upper parts of it move as a rule outwards with great speed up to 20-30 cm. per second. The lower parts of it move inwards with less speed. The depth of the outgoing current varies.

The larvae are found in the outgoing as well as in the ingoing curent. The fast-flowing surface layers are not so rich in larvae as the deeper inflowing layers; but then they run much faster, and thus transfer just as great masses of larvae as the slow-flowing deeper layers that are more apt to "stow up" the larvae or pack them more closely together. Tides are in this locality of very small account, amounting only to about 10 centimetres.

Changes may occur in the above-sketched current system. A westerly gale lasting some days will thus blow nearly all the surface water away from these fiords, and bring the salt bottom water, from 20-30 metres depth, right to the surface. After such a gale the salt bottom water will again drop down and pull over it a strong, deep, ingoing water-layer from the Skagerrak. Rises and falls in the deep salt-layers of the Skagerrak will produce the same effect. A diagram showing the alterations in the water-layers contemporaneous to the tow-nettings, which I have mentioned above, will clearly illustrate the great changes which took place in the Sōndeledfiord as well as also in the neighbouring fiord, the Sandnesfiord. The water-layer, in which the larvae mainly live (the white layer between 20 and 30 per thousand salinity), and where the isopykn of 1,021 is drawn, is subjected to great changes. The salt bottom water rises, sweeps all the water above 20 m. depth out of the fiord, then again drops and sucks in new water of low salinity from the Skagerrak.

Exactly the same changes occur in the Skagerrak, where contemporaneous observations were made two

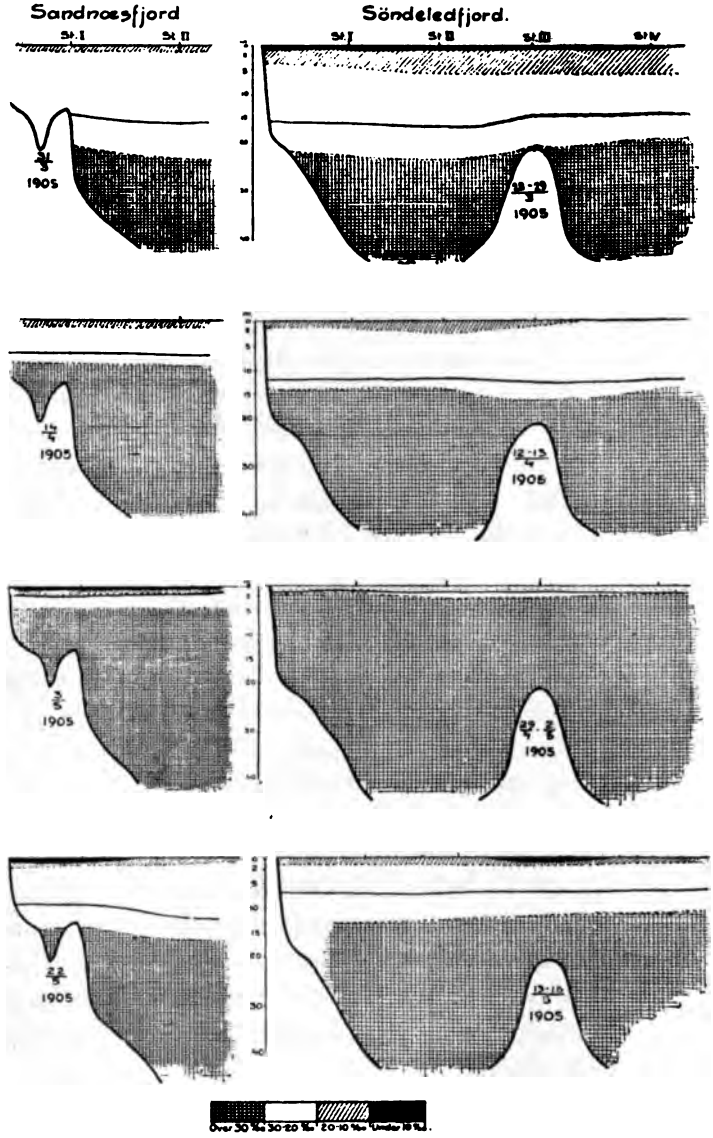



FIG. 4. Diagram showing hydrographical changes in the Sandnes and Söndeled fiords, Spring, 1905.

miles from the coast. On April 1st the isopykn of 1,021 was at a depth of 18 m.; on April 14th, at 8 m.; on May 3rd at the surface and on May 23rd at 8 m. again.

Along with these great changes of the surface layers in the fiords great changes were also observed in the

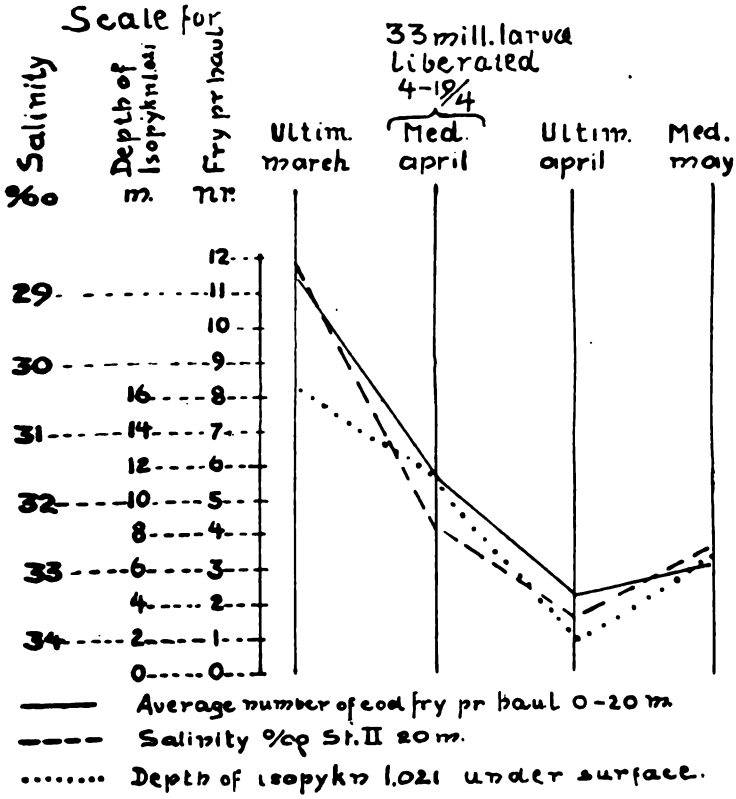



Fig 5.

number of cod larvae, as mentioned above, and also in the number of other fish larvae. The above diagram shows the relation between the rise and fall of salinity, the isopykn of 1,021 and the average number of cod larvae per haul in the Söndeledfiord on the four occasions mentioned on page 115. (See Fig. 5.)

In this diagram the four vertical lines denote the four dates of the investigation. The unbroken curve denotes the average number of cod larvae per 5-min. tow-nettings at 1 m. depth and 250 metres length, calculated by integration of the figures gained by the 20 tow-nettings, which were made on each occasion at the four stations in the fiord. The broken curve shows the alterations in salinity at 20 m. depth in the middle station. The dotted curve denotes the distance under the surface, where, on the same station, the specific gravity of the water *in situ** was 1,021, a value the importance of which has previously been mentioned.

If we study this diagram we shall observe that the decrease in the number of larvae closely follows the upheaval of the salt water and the rise of the isopykn of 1,021 towards the surface, expelling the "fry water" of lower salinity. When the salinity again was lowered and the isopykn of 1,021 again subsided the number of larvae rose.

Similar phenomena were observed also in the Sandnesfiord, and the circulation in this fiord being quicker, the alterations in the numbers of fry† were here still greater. Also a study of the occurrence of the Pleuronectid larvae shows exactly the same great decrease in their number parallel to the expulsion of the upper water-layer in which they lived.

These facts seem to me to indicate an intimate connection between the movements of the water and the movements of the eggs, larvae and fry. There is evidently a more or less constant circulation of pelagic fry connected with the circulation of the waters. The pelagic fry evidently drift in and out according to the changing

* The weight of the water in grams per c.cm.

† Also the number of eggs decreased more rapidly in this fiord.

movements of the water-masses. The pelagic cod fry may, therefore, not be considered as belonging to a certain small fiord or locality. It forms a moving and changing part of the stock of fry belonging to a far greater area of water.

As the movements of the water masses differ in different years, they would be expected to produce annual variations in the occurrence of the fry. This has, indeed, proved to be the case. In May, 1904, there was a very weak Baltic current and plenty of western water in the Skagerrak.* All the summer there were large masses of drifting fry to be *seen* in the sea and especially in the beginning of June they were very numerous. I could nearly everywhere note their presence, by direct observation, under the drifting jellyfish, and easily catch them with a small hand net. I could anchor my boat in the open Skagerrak off Risör, and observe the pelagic young of cod, haddock, and whiting in great masses drift past under the jelly-fish with a speed of 3-4 knots. The sea was quite full of jelly-fish and under nearly every one of them swam one or several young fish, which easily were caught for examination. By towing my small tow-net (1 m. diam.) for five minutes, I could catch up to 39 cod, haddock, and whiting of 2 to 3 cm. length. The "Michael Sars" found these young fish distributed in the upper layers over the whole of the deeper Skagerrak, and there can be no doubt as to these young having drifted out from shallow water, because no cod spawn in the deep Skagerrak.

In 1905 things were entirely different. This year there was a strong Baltic current.† During the early

* See Bulletin of International Council for the study of the sea.

† See Bulletin of the International Council for the Study of the Sea, 1904-5.

summer no young fish were, with a few exceptions, observed by me under the jelly-fish. Hauls of very great duration had to be made to prove their presence even in scanty numbers. In late summer their number seemed to increase under the jelly-fish, and in autumn the young of the whiting were for the first time to be seen in great numbers under the jelly-fish.

The investigations with seines, undertaken by Mr. Dannevig and me in common, as well as by me alone, also shewed a marked difference in the number of littoral fry obtainable in the two years. In 1904 I ascertained that the young cod 3-4 cm. long, as early as in the last days of May, occurred in the Zostera along the shores of the Söndeledfiord, the coast outside and in the Sandnesfiord. Their numbers constantly increased and they were to be found everywhere along the coast, even in the Christianiafiord, in great numbers.

In 1905 things were quite different. The facts are clearly shown by the following diagram (fig. 6), giving the average number of cod fry obtained per haul in the different fiords examined in July-August in the two years.

It is easily seen that the summer 1904 everywhere is characterised by a relative abundance of fry. The greatest abundance occurred in the open fiords Sandnesfiord and Stölefiord, which both have a lively circulation of water. Even in the Kristianiafiord, which by previous investigations (1898-99) was found to have a very poor stock of fry during summer was now relatively rich.

The summer of 1905 was characterised by great poverty.* In the Kristianiafiord the poverty was, for example, just as prominent as Hjort found by his investigations in 1898 and 1899. The Hellefiord, where 10

* The temperatures and salinities were in both years practically the same in the fiords investigated.

millions of larvae were liberated in spring, was very poor. The Söndeledfiord where 33 millions were liberated was a little richer. But the inner part of the fiord, where the majority of the fry was liberated was exceedingly poor. The greater part of the fry caught in this fiord belongs to the section of the fiord nearest to the coast and the "Skiaergaard." This part was examined a couple of weeks later than the inner part

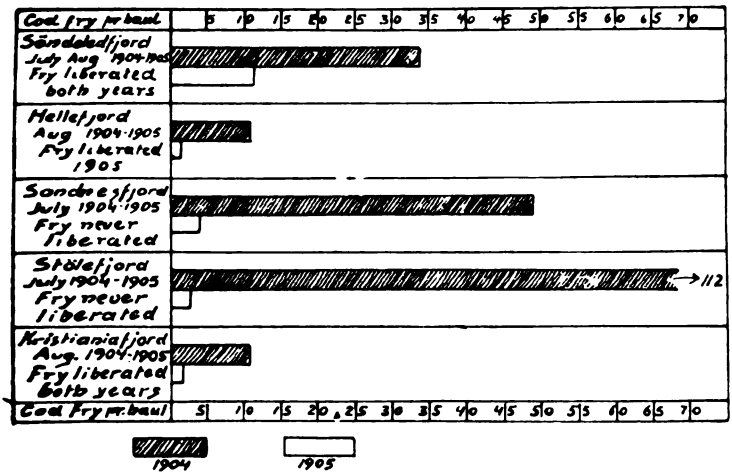



FIG. 6. Diagram showing the average number of cod fry obtained per haul with fine-meshed seines in the fiords examined, July-August.

of the fiord and about three weeks later than the Sandnes and Stole fiords. It can be proved that the number of fry increased during this time, because also the Sandnesfiord early in September was much richer in fry than it was in July. A similar diagram (fig. 7) showing the results for September-October will show this still more clearly.

A comparison with fig. 6 will immediately show

that the number of fry had largely increased in the Sandnesfiord as well as the Stölefiord.*

These diagrams indicate the conclusion that when *there is a scarcity of fry, this scarcity is common to a large stretch of coast, and when there is an abundance of fry, this abundance may be observed everywhere within a certain large*

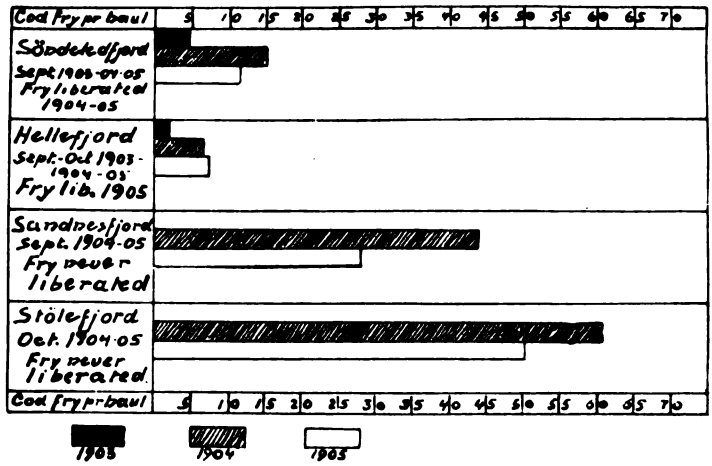



FIG. 7. Diagram showing average number of cod fry obtained per haul with fine-meshed seines in fiords examined, Sept.-Oct.

*area. The addition of artificially hatched cod larvae to a locality seems nowhere to influence the relative abundance of littoral fry in a recognisable degree.*

These facts, of which I have here briefly drawn the main outlines, seem to me to leave little hope as to the possibility of carrying out a fish culture, or locally

* The investigations in Sept.-Oct. in the Söndeledfiord and in the Hellefiord were made with a more coarse-meshed seine than mine. This seine (Mr. Dannevig's seine, see page 111) must have let nearly all the very small fry (under 6-7 cm.) pass through the meshes, the cloth in the middle being then removed. In July-August the seines fish about alike. The results from autumn may thus in these two fiords not *directly* be compared to the autumn results in the Sandnes and Stöle fiords. Both of these were examined with my seine, which could catch all sizes.

influencing the number of littoral fry by means of liberating artificially hatched cod larvae.

An exact proof is, of course, impossible to give, as it is impossible to follow and recognise the different individuals during development. A circumstantial proof or a calculation of possibilities is all we are able to attain. And our opinion of the matter must be formed on such judgment.

As I have mentioned before, my investigations have proved that the fiords themselves produce such quantities of cod eggs and larvae that the numbers which we can produce from the hatchery at a reasonable price are small in proportion to the natural production. The liberated larvae are distributed by the current and mixed with the stock of fry belonging to far greater areas. In this way its importance to the naturally existing fry is still further lowered. Our investigations of the occurrence of the littoral fry give a clear impression of this. As far as I can see the present proofs all point to the conclusion, that the natural laws and causes which determine the growth and distribution of the cod fry along the coast seem to be so powerful that the influence of the small and limited numbers of larvae which we possess the power of liberating, cannot be traced. Evidently these larvae disappear as an insignificant and unrecognisable part of the great mass of fry belonging to a larger area.

# REPORT ON EXPERIMENTS WITH MARKED FISH DURING THE YEAR 1906.

By Jas. Johnstone

The experiments with marked fishes begun in 1904 were continued during 1906. It was our intention to mark 1,000 fishes during this year, but for various reasons little more than half that number were dealt with. At the beginning of the year it was suggested to me that the plaice caught in the course of the ordinary trawling experiments carried on by the "John Fell" should be marked and liberated—that is, that special cruises for the purpose of catching fish for marking experiments should not be made, but the routine trawling experiments should be utilised for this purpose. This policy was adopted, and with one or two exceptions the fish marked and liberated were caught on the ordinary trawling stations visited as a matter of routine by the "John Fell." From several points of view this method is to be recommended, but the general result has been that smaller lots of fish were liberated than was desirable. In future it would probably be better to concentrate these experiments, and spend more time on each, catching and liberating larger numbers of fish at fewer stations. Experience of the distribution and migration of plaice has convinced me that quarterly marking experiments (roughly speaking) would probably give the best results. The fish should be liberated about the end of October or beginning of November, then in February or March, then in June or July, and possibly also in September. In this way we should make the experiments correspond with the times when the fish are changing their habits.

Pressure of other work interfered at times with the experiments of 1906. It was not always an easy matter to obtain sufficient quantities of fish of suitable sizes. Then during November and December very rough weather was experienced, and some projected experiments had to be abandoned.

As in former years, I am greatly indebted for assistance in these experiments. Both Dr. Jenkins and Capt. Wignall have given every facility and displayed great forbearance during the prosecution of experiments which have, no doubt, tended to disturb the usual routine of the patrol work of the "John Fell." As in former years, the chief Fishery officers have given indispensable assistance in receiving and forwarding marked fishes handed them by fishermen. Several members of the Sea Fisheries Committee (Messrs. Harley, Dean, Houldsworth, Saycell and Garnett) have also given invaluable assistance, and several gentlemen (Mr. Robert Knox, Douglas; Mr. A. J. Rust, of the Milford Haven Committee; Mr. F. B. Rees, Milford Haven; and the Customs' officers of that port—Mr. T. Parker, Glenluce; Professor D'Arcy Thompson, Dundee; and Mr. E. W. L. Holt, of the Irish Department of Agriculture and Technical Instruction), quite unconnected with the Lancashire and Western Sea Fisheries Committee, have given every assistance.

During 1906, 683 plaice and other fishes were marked and liberated. Of this total number 88 were flounders, 38 were dabs and 13 were small brills. One large cod was also marked and liberated, but was not heard of again. No soles were dealt with, as our former experience (and that of other investigators) of marking this fish has been unfavourable. Flounders give very favourable results, and so also do brill. Dabs, on the other hand, do not

withstand the marking operations with much success. Both dabs and soles have strongly ctenoid scales. These are probably used to some extent for purposes of locomotion, and the fishes no doubt drag themselves along the sea bottom by means of their rough skin, and in so doing cause the attached label and button to chafe the flesh and cause a bad wound. Soles, and probably dabs, are also more susceptible to slight skin abrasions than plaice or flounders.

As before, it is no doubt the case that marked fishes have been caught and were not reported. I have heard of several such cases. Capt. Wright, Chief Fishery Officer at Fleetwood, reported the finding of several marked fishes, and information as to one reached me from a friend in Cairo. In most of these cases identification of the number of the label was impossible, so they are not included in the lists given in this report.

The summary table on pages 130 and 131 shews the stations of 1906, the numbers of fishes liberated and returned and the percentages of recapture. It also includes the numbers of marked fish liberated in 1904-5 which have been returned during the past year. Before discussing the experiments of 1906, the latter may be considered.

It will be most convenient for the reader if I present the results of the experiments in the form adopted by the German investigators, working under the International Fishery Investigations Scheme.

"The analyses of size of fish" give the numbers of fishes marked and liberated. Sizes were always measured to the nearest quarter of an inch.

For convenience, the headings of the columns in the tables giving particulars of the fishes returned are numbered as follows:—

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| No. of label | Size when liberated Inches | Place of recapture | Date when recaught | Time in the Sea Months | Size when recaught Inches | Increase in size Inches | Method of recapture |

The symbols (8) denoting method of fishing by which the marked fishes were recaptured are:—ST, steam trawler; 1T, 1st class sailing trawler; 2T, 2nd class trawler (shrimper or fish trawler); TN, trammel net; SN, stake net; GN, gill net; B, baulk; T, "tees."

Sizes are given to the nearest $\frac{1}{8}$th inch. "Time in the sea" is given in months (4-weekly periods).

FURTHER RESULTS OF THE EXPERIMENTS IN 1904-5.

Thirty-four fishes liberated in the course of the experiments of 1904 and 1905 have been recaptured during the present year. With the exception of experiments 21 and 22, 1905 (October, Luce Bay and Formby Channel), these further results obtained do not materially modify the percentages of recaptures given in the Summary Table published in the last Annual Report.* Interesting results with reference to the migrations and rate of growth of plaice are yielded by these recaptures, but these will be referred to later in this Report. In the meantime I give the particulars with regard to the recovery of the fishes in question:—

Experiment 4, 12th November, 1904.

Station: 1½ miles N.W. from Great Ormes Head.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L104 | 8¼ | N. by W. from Ballycottin island, S. coast of Ireland. | 12/11/06 | 26 | 15½ | 7¼ | ST |

This fish has, therefore, been exactly two years in the sea before it was recaught.

* Report for 1905 Lancashire Sea Fisheries Laboratory, 1906, pp. 108-150.

## GENERAL SUMMARY:—
## STATIONS AND NUMBERS OF FISHES LIBERATED AND RETURNED.

| | Station where Fish Liberated. | Date. | No. Liberated. | No. Returned. | Percentage Returned. |
|---|---|---|---|---|---|
| 1 | Near Great Ormes Head | 1/2/06 | 44 plaice | 10 | 23% |
| | | | 7 dabs | 1 | |
| 2 | Near Fleetwood | 19/2/06 | 35 plaice | 16 | 46% |
| 3 | Bahama Bank | 20/2/06 | 10 plaice | 4 | 40% |
| | | | 10 flounders | 3 | |
| 4 | Near Puffin Island | 21/2/06 | 8 plaice | 2 | 25% |
| | | | 5 flounders | 1 | |
| | | | 1 cod | | |
| 5 | Near Blackpool | 5/3/06 | 18 plaice | 6 | 33% |
| | | | 12 flounders | 3 | |
| | | | 9 brill | 4 | |
| 6 | Colwyn Bay | 6/3/06 | 23 plaice | 6 | 26% |
| | | | 19 dabs | 2 | |
| | | | 2 flounders | 1 | |
| 7 | Blackpool Closed Ground | 30/3/06 | 23 plaice | 2 | 9% |
| | | | 5 dabs | | |
| 8 | Outside Walney Island | 31/3/06 | 28 plaice | 8 | 29% |
| | | | 9 flounders | 4 | |
| | | | 5 dabs | | |
| 9 | Near Piel | 9/5/06 | 49 flounders | 9 | 18% |
| 10 | Near Nelson Buoy | 12/6/06 | 40 plaice | 21 | 52% |
| 11 | Near Pwllheli | 13/6/06 | 41 plaice | 2 | 5% |
| | | | 1 flounder | | |
| 12 | Off Llanrhystyd | 14/6/06 | 46 plaice | 4 | 9% |
| | | | 4 brill | | |

| | | | | | |
|---|---|---|---|---|---|
| | | | 1 dab | | |
| 15 | Near Nelson Buoy | 9/7/06 | 50 plaice | 10 | 20% |
| 16 | Off Penkilan | 12/7/06 | 50 plaice | 2 | 4% |
| 17 | Red Wharf Bay | 19/9/06 | 41 plaice | 7 | 17% |
| 18 | Luce Bay | 3/10/06 | 50 plaice | 1 | 2% |
| | **Experiments of 1906:** Totals to end of Dec., 1906 :— | | | | |
| | Plaice | | 543 | 105 | 19% |
| | Flounders | | 88 | 21 | 24% |
| | Brill | | 13 | 4 | 30% |
| | Dabs | | 38 | 3 | 8% |
| | Cod | | 1 | 0 | — |
| | Total | | 683 | 133 | 19% |
| | **Experiments of 1904-5 :—** | | | | |
| | Experiments 4, 7, 10, 14, 16, 17, 20, 1904-5 | Plaice... | — | 11 | — |
| | Experiment 21, 1905 | ,, ... | 20 | 8* | 40% |
| | Experiment 22, 1905 | ,, ... | 43 | 19† | 44% |
| | Total fishes returned in 1906 | | | 167‡ | |

* Includes 1 fish returned during 1905. † Includes 3 fishes returned during 1905.
‡ See above notes.

Experiment 7, 18th November, 1904.

Station: Luce Bay.

Four fishes are to be added to the former list.*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L242 | 8 | Off Chapelrossen, Luce Bay, 5 fathoms. | 7/2/06 | — | 12½ | 4½ | GN |
| L252 | 8½ | 4 miles W.N.W. from Whitehaven Pier. | 28/2/06 | — | 10 | 1½ | 1T |
| L287 | 8¾ | Off Largs, Firth of Clyde | 12/11/06 | — | 15 | 6¼ | 2T |
| L288 | 8¾ | Off Stairhaven Harbour, Luce Bay. | 4/9/06 | — | 15¼ | 6½ | GN |

Experiment 10, 17th March, 1905.

Station: 5 miles W. from Morecambe Bay Lightship.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L490 | 8¾ | 10-12 miles S.E. from Maughold Head, 12 fathoms. | 14/7/06 | — | — | — | ST |

Experiment 14, 6th July, 1905.

Station: 2 miles W.S.W. from Liverpool Bar Lightship.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L528 | 10 | Caldy Island bearing N.W., 15 miles distant. | 10/7/06 | — | 14 | 4 | 1T |
| L541 | 8¾ | 10 miles W.S.W. from Smalls Light, 57 faths. | 17/9/06 | — | 14½ | 5¾ | ST |

Experiment 16, 12th July, 1905.

Station: Near Bahama Lightship.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L587 | 9 | 8 miles S.W. from Morecambe Bay Light Ship. | 7/7/06 | — | 10¾ | 1¾ | 1T |

## Experiment 17, 13th July, 1905.

Station: Blackpool Closed Ground.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L821 | 7 | Morecambe, opposite old Pier 3 fathoms. | 30/12/05 | — | — | — | 2T |

## Experiment 20, 22nd July, 1905.

Station: 5 miles N.W. by W. from Aberystwyth.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L848 | 8¾ | Horse Channel, Fairway, 10 fathoms. | 26/9/06 | — | 12⅛ | 3⅜ | 2T |

## Experiment 21, 13th October, 1905.

Station: Luce Bay.

Fish caught in Luce Bay.

### Analysis of Sizes of Fish Liberated.

| Sizes (inches) | 8 | 9½ | 10 | 10¼ | 10½ | 10¾ | 11 | 11¼ | 12 | 12½ | 12¾ | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 2 | 1 | 1 | 2 | 5 | 1 | 2 | 2 | 1 | 1 | 1 |

### Analysis of Sizes of Fish Returned.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L860 | 11¼ | 5 miles W. from Stairhaven Harbour, Luce Bay, 7 fathoms. | 31/7/06 | 10 | 14 | 2¾ | GN |
| L868 | 8 | Off Sand Head, Luce Bay | 24/8/05 | 1 | — | — | GN |
| L864 | 10¾ | 5 miles W.S.W. from Stairhaven Harbour, Luce Bay, 6 fathoms. | 25/6/06 | 10 | 13 | 2¼ | GN |
| L875 | 12½ | 2 miles W. from Stairhaven Harbour, Luce Bay. | 23/4/06 | 7 | 12¾ | ¼ | GN |
| L865 | 10¾ | Probably near Maughold Head, I.O.M. | 1/2/06 | 4 | 10¾ | — | ST |
| L870 | 10½ | 17 miles N.W. from Piel Gas buoy. | 17/2/06 | 4 | 10¾ | ¼ | 1T |
| L876 | 12¾ | 8 miles W. by S. from Selker Light Ship. | 17/3/06 | 5 | 13½ | ½ | ST |
| L871 | 10¾ | 6 miles E. from Balbriggan, Co. Meath, Ireland. | 25/7/06 | 10 | 12¾ | 2 | — |

Experiment 21 of 1905 was made while trawling in Luce Bay for mature plaice for Piel Hatchery. Twenty fishes were liberated, and during the next twelve months eight of these were returned. Four of these were recaptured in Luce Bay itself, not far from the place of original capture. An interesting result from this experiment is that for the first time we have observed a migration from Luce Bay into the Irish Sea. Previously the fishes marked in Luce Bay were recaught in their original habitat, in the Firth of Clyde, or in the Solway, but three (Nos. L865, L870, L876) of the lot here considered were recaught in the Northern part of the Irish Sea and one (L871) on the East Coast of Ireland, which it probably reached after traversing the waters East of the Isle of Man.

Experiment 22, 26th October, 1905.

Station: Entrance to Formby Channel.

Fish caught in Rock Channel.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10¼ | 10¾ | 12¾ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 8 | 9 | 11 | 5 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L904 | 10¼ | 2 miles N.N.W. from Liverpool Bar Light Ship, 13 fathoms. | 26/9/06 | 12 | 13½ | 3¼ | 2T |
| L910 | 8¼ | Rock Channel ..... | 31/10/05 | 1 | — | — | 2T |
| L917 | 8¾ | N.N.W. from Liverpool Bar Light Ship, 17 faths. | 12/8/06 | 10 | 10 | 1¾ | 1T |
| L918 | 8¼ | Off Newcome Knoll ..... | 21/11/05 | 1 | — | — | 2T |
| L920 | 9¼ | Horse Channel ..... | 17/11/05 | 1 | — | — | 2T |
| L925 | 8¾ | 2 miles N. from Formby Channel Fairway Buoy. | 2/5/06 | 7 | 9 | ¼ | 2T |
| L936 | 8¼ | Rock Channel, 5 faths.... | 19/3/06 | 5 | 8½ | ¼ | 1T |

PARTICULARS OF FISH RETURNED—*continued.*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L941 | 8 | Formby Channel, near N.W. Buoy. | 9/8/06 | 10 | 9¼ | 1¼ | 2T |
| L942 | 8¼ | 12 miles N. from Liverpool Bar Light Ship, 15 fathoms. | 5/8/06 | 10 | 10 | 1¾ | 1T |
| L903 | 8 | Boghole, Ribble ..... | 17/4/06 | 6 | 8 | — | 2T |
| L913 | 8¼ | S. side of Ribble, opposite Ansdell Buoy. | 26/4/06 | 6 | 8¾ | ½ | SN |
| L934 | 8 | Bog Hole, near Birkdale Gas Buoy. | 1/5/06 | 7 | 8⅝ | ⅝ | 2T |
| L935 | 8¼ | Jumbo Buoy, Southport | 4/3/06 | 5 | 8¼ | — | 2T |
| L938 | 7¾ | Off Jumbo Buoy ..... | 27/9/06 | 2 | 10½ | 2½ | 2T |
| L901 | 8½ | Lune, near Glasson Dock Light. | 18/12/05 | 2 | 8½ | — | 2T |
| L939 | 8½ | Roosebeck Scar, Morecambe Bay. | 3/12/05 | 2 | 8½ | — | SN |
| L912 | 8¼ | Mostyn Deep, Dee ..... | 14/12/05 | 2 | 8¼ | — | 2T |
| L908 | 8 | 4 miles S.W. from Morecambe Bay Light Ship. | 11/8/06 | 10 | 9¼ | 1¼ | 1T |
| L906 | 8¾ | 25 miles N. from Smalls Light. | 2/9/06 | 11 | 11¼ | 2½ | ST |

Experiment 22 of 1905 (Chart I.) gives results which are fairly consistent with those of other experiments. If consideration be paid to the length of time that has elapsed between liberation and recapture, I think the movements of the plaice indicate winter alongshore and summer offshore migrations. Thus all the plaice (7) recaptured within the two months after liberation were found in the shallow waters in the channels and on the edges of the banks. Four have travelled towards the Cheshire shallow waters, and three towards Ribble and Morecambe Bay. Then we have a group of five fishes recovered about the fifth and sixth month after liberation in the Southport and Mersey Channels. These have probably remained there after the initial inshore migration. Finally, there is a group of six fishes which have migrated, or are migrating out from the territorial zone, and were found after seven to twelve months in relatively deep water.

**Experiment 1, 1st February, 1906.**

Station: Between Great Ormes Head and Conway Bar Buoy.

Fish caught in five hauls between Red Wharf Bay and N. Constable Buoy.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Size (inches) | 7¼ | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 3 | 2 | 6 | 2 | 4 | 4 | 1 | 2 |
| No. of dabs | — | 1 | — | 1 | — | — | — | 1 | 1 |

| Size (inches) | 9½ | 9¾ | 10 | 10¼ | 10½ | 11 | 11½ | 12½ | 13 |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 6 | 1 | 2 | 3 | 1 | 2 | 1 | 1 | 1 |
| No. of dabs | — | 1 | — | 1 | — | 1 | — | — | — |

PARTICULARS OF FISH RECAUGHT.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L712 | 9½ | 4 miles N.W. from Great Ormes Head, 14 faths. | 5/8/06 | 6 | 10⅛ | ⅛ | 1T |
| L716 | 10¼ | Conway Bay, 5 fathoms... | 13/11/06 | 10 | 13¼ | 3 | 1T |
| L721 | 8½ | N.W. from Great Orme, 15 fathoms. | 30/9/06 | 8 | 11¼ | 2¾ | 1T |
| L733 | 8 | Off Great Ormes Head ... | 13/8/06 | 7 | 8⅞ | ⅜ | 1T |
| L747 | 9 Dab | 2 miles W. from Great Orme. 5 fathoms. | 3/5/06 | 4 | 9⅛ | ⅛ | 1T |
| L734 | 8¾ | N.N.W. from Liverpool Bar Light Ship, 17 fathoms. | 12/8/06 | 7 | 10⅝ | 1⅞ | 1T |
| L713 | 9½ | 1 mile S.W. from Nelson Buoy. | 21/9/06 | 8 | 11½ | 2 | 2T |
| L728 | 8½ | Near Bar Buoy, Ribble... | 20/3/06 | 2 | 8½ | — | 2T |
| L702 | 10¼ | 7 miles S.W. from Morecambe Bay Light Ship. | 14/7/06 | 6 | 12⅜ | 1⅞ | 1T |
| L709 | 9¾ | Holyhead Harbour, 5 fathoms. | 19/4/06 | 3 | 10½ | ¾ | 'Set net' |
| L726 | 10 | Off Llanon, Cardigan Bay | 10/7/06 | 6 | 10¼ | ¼ | — |

No decided conclusion can be drawn from the results of this experiment. It will be seen from the results, which are represented on Chart II., that four of the fishes returned have travelled to the North. Six were found in

the Red Wharf Bay area, while two have gone to the Western District, one being found in Holyhead Outer Harbour, and one off Llanon in Cardigan Bay.

Experiment 2, 19th February, 1906.

Station: Near No. 1 Buoy, Entrance to Wyre, Fleetwood.

Fish caught in Rivers Lune and Wyre.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Size (inches) | 8 | 8¼ | 8½ | 8¾ | 9 | 9½ | 9¾ | 10 | 10¼ | 10½ | 11 | 11¼ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 5 | 6 | 2 | 4 | 4 | 2 | 1 | 1 | 4 | 1 | 3 | 2 |

PARTICULARS OF FISH RECAUGHT.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L758 | 10¼ | Pilling Sands ..... | 28/2/06 | 1 | 10¼ | — | Tees |
| L763 | 9 | Pilling Sands ..... | 20/4/06 | 2 | 9½ | ½ | SN |
| L772 | 8¾ | S. side of Lune, near No. 5 Buoy. | 11/4/06 | 2 | 9 | ¼ | SN |
| L774 | 8¼ | Below Morecambe, W. end Pier. | 23/3/06 | 1 | 9¼ | ¾ | 2T |
| L775 | 8¼ | Lune, near No. 4 Buoy... | 7/4/06 | 2 | 8½ | ¼ | 2T |
| L785 | 8 | Pilling Sands ..... | 26/5/06 | 3 | — | — | SN |
| L755 | 11 | 1 mile N.W. from St. Anne's Pier. | 7/3/06 | 1 | 11 | — | 2T |
| L756 | 11¼ | 16 miles N.N.W. from Liverpool Bar Light Ship. | 1/7/06 | 5 | 13⅝ | 2⅜ | 1T |
| L777 | 8¼ | 12 miles N. from Liverpool Bar Light Ship, 15 fathoms. | 5/8/06 | 6 | 10⅞ | 2⅝ | 1T |
| L781 | 8½ | 10 miles N.N.W from Liverpool Bar Light Ship, 13 fathoms. | 1/9/06 | 7 | 10½ | 2 | 1T |
| L783 | 8 | Near Formby beach mark | 28/3/06 | 1 | 8 | — | 2T |
| L761 | 9½ | 4 miles S. from Bahama Light Ship. | 7/12/06 | 10 | 12¾ | 3¼ | 1T |
| L766 | 9 | 4 miles S. from Morecambe Bay Light Ship, 18 fathoms. | 1/7/06 | 5 | 10¾ | 1¾ | 1T |
| L754 | 11 | Between Barrels and Saltees Light Ships. | 18/4/06 | 2 | 11 | — | ST |
| L762 | 8¾ | North Bay, Co. Wexford, Ireland, 3½ fathoms. | 28/11/06 | 10 | 11⅛ | 3⅛ | — |
| L780 | 8¼ | — | 4/12/06 | 10 | 10⅞ | 2⅝ | ST |
| L782 | 8 | — | 4/12/06 | 10 | 11 | 3 | ST |

Experiment 2 shows again the decided contrast between the winter alongshore and the summer offshore migrations. The results are shewn on Chart II. by black circles. Remembering that the lines connect the station of liberation with the points of recapture of the fishes, we see that the fishes recaught fall into two well-marked groups—(1) a group of eight fishes recaught within the first three months after liberation, that is before the end of May, and (2) a group of five fishes recaptured from five to ten months afterwards. The former fishes were all recaught in the shallow waters in Morecambe Bay and in the Ribble and Mersey Estuaries by stake-nets, "tees" and second class trawlers; while the latter fishes were recaptured in relatively deep and distinctively offshore waters by first class vessels. It must be pointed out that the straight lines and arrow-heads do not in this latter case represent the actual paths followed by these fishes. Probably *all* those liberated immediately moved into inshore waters, where some were caught, and then after a sojourn there of two or three months the remnant migrated offshore, where a further proportion were recaptured. Two recaptures are not shewn in the chart. One of the fishes was found off the coast of Wexford, in Ireland, and the other on the South Coast of Ireland. This latter fish had in two months made a migration of, at the very least, 170 nautical miles. Two other fishes were caught offshore (by steam trawlers) after ten months, but the exact locality cannot be traced.

Experiment 3, 20th February, 1906.

Station: Bahama Bank.

Fish caught on "shoals" and in "Hole."

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 9¼ | 9¾ | 10 | 10¼ | 10½ | 10¾ | 11 | 11½ | 11¾ |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | — | 1 | 3 | 2 | 2 | — | 1 | — | 1 |
| No. of flounders | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | — |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L894 | 10¼ Flounder | Silverdale Sands ..... | 20/5/06 | 3 | — | — | SN |
| L896 | 11 Flounder | Foxfield, River Duddon... | 19/7/06 | 5 | 11⅜ | ⅜ | B |
| L880 | 10 | 10 to 12 miles S.E. from Maughold Head, 12 fathoms. | 26/7/06 | 5 | 12¼ | 2¼ | ST |
| L882 | 10 | Fish Market, Blackburn... | 3/4/06 | 2 | 10 | — | — |
| L883 | 8½ | Fish Market, Blackburn... | 5/6/06 | 4 | 10⅝ | 2⅜ | — |
| L888 | 11¾ | 8 miles S.W. by W. from Selker Light Ship. | 19/3/06 | 1 | 12 | ¼ | ST |
| L891 | 10 Flounder | 5 miles S.E. from Bahama Light Ship. | 24/2/06 | 1 | 10 | — | ST |

Experiment 3 gives no useful results. It will be noticed (see Chart II., circles with a horizontal line) that two of the flounders originally caught in Manx offshore waters were recaptured in the Duddon and in Morecambe Bay. The plaice recaptured were all found in offshore waters. Two of these latter fishes could not be traced with certainty.

**Experiment 4, 21st February, 1906.**

**Station:** ½ mile N.W. from Puffin Island.

**Fish caught on Bahama Bank.**

ANALYSIS OF SIZES OF FISH LIBERATED.

| Size (inches) ... | 9 | 10¼ | 10½ | 10¾ | 11¼ | 11½ | 11¾ | 12 | 12¾ | 13½ | 15 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice ... | 1 | 1 | 1 | 1 | — | 1 | 1 | 1 | 1 | — | — | — |
| No. of flounders | 1 | — | — | — | — | 1 | — | — | 1 | 1 | 1 | — |
| No. of cod ..... | — | — | — | — | — | — | — | — | — | — | — | 1 |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L794 | 11¾ | 8 miles S.W. by W. from Selker Light Ship. | 19/3/06 | 4 | 12 | ¼ | ST |
| L792 | 11½ | 4 miles N.E. from Cardy Rocks, Balbriggan, Ireland. | 27/4/06 | 2 | — | — | — |
| L788 | 11¼ Flounder | Off Connah's Quay, Dee... | 12/7/06 | 5 | 11½ | ¼ | TN |

The fishes liberated in this experiment were a few which had been kept on board the "John Fell" while making a passage from Isle of Man to Red Wharf Bay. They were caught on Bahama Bank and liberated off Puffin Island. The number of recaptures is too small to enable any conclusion to be made.

## Experiment 5, 5th March, 1906.

Station: 7 miles W.N.W. from Blackpool North Pier.

Fish caught in Rivers Lune and Wyre.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) ... | 8 | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10 | 10¼ | 10¾ | 11 | 13 | 13½ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice ... | 3 | 2 | 5 | 2 | 1 | 1 | 2 | — | 2 | — | — | — | — |
| No. of flounders | 1 | — | — | 2 | — | 3 | — | — | 1 | 1 | 1 | 2 | 1 |
| No. of brill ..... | — | — | — | 1 | — | 1 | 2 | 1 | 3 | 1 | — | — | — |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L956 | 8¾ | Near W. end Pier, Morecambe. | 16/4/06 | 2 | 8¾ | — | B |
| L966 | 9 Flounder | 1 mile below Humphrey Head. | 15/6/06 | 3 | 10½ | 1¼ | B |
| L975 | 8 Flounder | Pilling Sands ..... | 26/5/06 | 3 | — | — | SN |
| L979 | 9½ Flounder | Lune, Cockerham Bank | 12/6/06 | 4 | 10½ | 1 | — |
| L981 | 10 Brill | Sunderland Bank ..... | 16/5/06 | 3 | — | — | SN |
| L962 | 10½ Brill | Pinfold Channel, Ribble... | 18/4/06 | 2 | 10¼ | — | 2T |
| L944 | 10¼ | 8 miles N. from Liverpool Bar Light Ship. | 11/7/06 | 5 | 12 | 1¾ | 1T |
| L958 | 10¾ Brill | Liverpool Bay, 16 faths.... | 9/8/06 | 6 | 13½ | 2¾ | 1T |
| L968 | 9 | 10 miles N.N.W. from Liverpool Bar Light Ship, 10 fathoms. | 24/8/06 | 6 | 12 | 3 | 1T |
| L945 | 8¾ | Probably near Morecambe Bay Light Ship. | 1/9/06 | 6 | — | — | — |
| L946 | 10¼ | S.W. from Morecambe Bay Light Ship, 25 fathoms. | 30/8/06 | 6 | 12⅜ | 2⅛ | 1T |
| L960 | 10½ Brill | 12 to 14 miles S.E. from Maughold Head, 12 fathoms. | 7/8/06 | 6 | 12⅛ | 1⅞ | ST |
| L964 | 8¾ | 15 miles W. from Blackpool, 21 fathoms. | 25/7/06 | 5 | 11⅛ | 2⅜ | 1T |

Experiment 7, 30th March, 1906.

Station: Blackpool Closed Ground.

Fish mostly caught in Luce Bay and kept in Piel tanks during winter.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) ..... | 7¼ | 7½ | 8 | 8¾ | 9 | 9¼ | 9¾ | 10 |
|---|---|---|---|---|---|---|---|---|
| No. of plaice ..... | 1 | 1 | 1 | 1 | 1 | 5 | 2 | 2 |
| No. of dabs ..... | — | — | — | 1 | — | — | 1 | — |

| Sizes (inches) ..... | 10¼ | 10½ | 11½ | 12¼ | 14½ | 14¾ | 15 | 15¾ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice ..... | — | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| No. of dabs ..... | 1 | 2 | — | — | — | — | — | — |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL47 | 10¼ | Birkdale shore ..... | 11/6/06 | 2 | — | — | SN |
| LL67 | 14¾ | 14 miles S.E. from Douglas | 18/4/06 | 1 | 15 | ¼ | ST |

Experiments 5 and 7 may be considered together. Experiment 5 was made with fish which were caught in Morecambe Bay, in the Lune and Wyre Estuaries. They were liberated off Blackpool Closed Ground, a closely adjacent area. Experiment 7 was made with a number of plaice and dabs which had been kept at Piel Hatchery during the previous winter. It is the custom to turn these fish out in Barrow Channel at the end of the spawning season, and we thought it might be useful to mark and liberate some of these fish. Only two out of twenty-eight fishes liberated have been returned (see Chart III., circles with superposed crosses). Probably the cause of this poor result is that the fish were possessed of little vitality, and the operation of marking was fatal to most of them.

Experiment 5, however, gives the usual result. Two groups of fishes may be distinguished (Chart III., circles)—(1) six fishes which travelled into Morecambe Bay and the Ribble Estuary, these were all recaptured within four months after liberation; and (2) six fishes recaptured from offshore waters five to six months after liberation. Of the fishes making the inshore migration, three were flounders and two brills. Of those making the offshore migration, probably at a later date, two were large brills and the rest were plaice.

## Experiment 8, 31st March, 1906.

Station: 4 miles W. by S. from Barrow Iron Works.

Fish caught on same ground.

### Analysis of Sizes of Fish Liberated.

| Size (inches) | 7¼ | 7½ | 7¾ | 8 | 8¼ | 8½ | 9 | 9¼ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 4 | 6 | 2 | 3 | 3 | 2 | 1 |
| No. of flounders | — | 1 | — | — | 1 | 1 | 1 | — |
| No. of dabs | — | — | 1 | — | 1 | 1 | 1 | — |

| Size (inches) | 9½ | 9¾ | 10 | 10½ | 11¼ | 11¾ | 13¾ |
|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 2 | 1 | — | — | — | — |
| No. of flounders | 1 | 1 | — | 1 | 1 | — | 1 |
| No. of dabs | 1 | — | — | — | — | — | — |

### Particulars of Fish Returned.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL76 | 9¾ | Bardsea Sands, Morecambe Bay. | 19/4/06 | 1 | 9¾ | — | SN |
| LL78 | 9½ | Baycliff Sands, Morecambe Bay. | 2/6/06 | 2 | 10¾ | 1¼ | SN |
| LL86 | 11¼ Flounder | Near Baycliff, Morecambe Bay. | 25/5/06 | 2 | 11½ | ¼ | SN |
| LL87 | 10½ Flounder | In Leven, Morecambe Bay. | 13/6/06 | 3 | 11 | ½ | SN* |
| LL102 | 7¾ | Off Haverigg Sea Wall... | 8/9/06 | 6 | — | — | L† |
| LL106 | 7½ | West Hollow, Morecambe Bay. | 23/4/06 | 1 | 7¾ | ¼ | SN |
| LL112 | 7½ Flounder | Bardsea Sands, Morecambe Bay. | 30/5/06 | 2 | 8 | ½ | SN |
| LL113 | 8¼ Flounder | 1 mile above Humphrey Head, Morecambe Bay. | 13/6/06 | 3 | 9¼ | 1 | B |
| LL98 | 8¼ | Off Nelson Buoy ..... | 13/7/06 | 4 | 9⅝ | 1⅜ | 1T |
| LL73 | 11¾ | 4 miles N.E. by E. from Morecambe Bay Light Ship. | 27/8/06 | 6 | 13 | 1¼ | 1T |
| LL100 | 7¾ | 9 miles S.W. from Morecambe Bay Light Ship. | 23/7/06 | 4 | 10 | 2¼ | 1T |
| LL104 | 8½ | 15 miles S.E. from Maughold Head. 12 to 15 fathoms. | 23/11/06 | 9 | 10¾ | 2¼ | ST |

* Salmon Net. † Line.

## Experiment 9, 9th May, 1906.

Station: 3 miles S. from Piel Gas Buoy.

Fish taken from Piel tanks, originally caught in Barrow Channel.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Size (inches) ... | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10 | 10¼ | 10½ | 11 | 11½ | 12¼ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of flounders | 3 | 2 | 7 | 4 | 2 | 8 | 6 | 5 | 5 | 3 | 2 | 1 | 1 |

PARTICULARS OF FISH RETURNED—ALL FLOUNDERS.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL117 | 9 | Barrow Channel ..... | 8/06 | 3 | 9 | — | SN |
| LL118 | 9 | 1½ miles below Humphrey Head. | 26/5/06 | 1 | 9½ | ½ | SN |
| LL123 | 9¼ | Kirby Pool, Duddon..... | 11/6/06 | 1 | 9¼ | ¼ | SN |
| LL131 | 9¼ | Baycliff Sands ..... | 14/5/06 | 1 | 9¼ | ¼ | SN |
| LL135 | 12¼ | Near Millom Pier, Duddon. | 18/6/06 | 1 | 12¼ | — | B |
| LL142 | 9¼ | Baycliff Sands ..... | 11/5/06 | 1 | 9¼ | — | SN |
| LL152 | 8½ | Foxfield, Duddon ..... | 21/5/06 | 1 | 9⅝ | ⅛ | B |
| LL154 | 10⅛ | Foxfield, Duddon ..... | 4/6/06 | 1 | 10⅜ | ⅛ | SN |
| LL157 | 10¼ | Bolton-le-Sands ..... | — | — | 10¼ | — | SN |

Experiments 8 and 9 may be considered together. Experiment 8 was made with plaice, flounders and dabs caught off Duddon Bar and liberated in a closely adjacent place. Experiment 9 was made with part of the stock of spawning flounders kept at Piel Hatchery and liberated annually. These fish were mostly caught in Barrow Channel. They were marked in the Hatchery and liberated near the entrance to Barrow Channel.

The results of Experiment 8 (Chart III.) indicate the usual two groups of recaptures. Four plaice and four flounders travelled inshore towards Morecambe Bay and the Duddon, and six were recaptured within the first three

months after liberation. On the other hand, five (four plaice and one flounder) were found in offshore waters from four to nine months afterwards.

Experiment 9 (Chart III.) indicates an inshore migration of flounders in the early summer. Not only did all the recaptures of flounders taken out from Piel take place in Morecambe Bay and in the Duddon, but four flounders caught outside Walney and liberated there made the same migration. The small numbers of flounders dealt with do not justify any attempt to construct the migration paths of this fish, but evidence of an inshore movement in the late spring or early summer appears to be forthcoming. All the flounders recaptured from the last experiment were fish in very fine condition. Without exception, all were feeding greedily on Lamellibranch molluscs (*Tellina scrobicularia*, *Mactra*) when recaptured.

### Experiment 6, 6th March, 1906.

Station: Colwyn Bay.

Fish caught in Colwyn Bay and in Conway Bay, two hauls.

Analysis of Sizes of Fish Liberated.

| Sizes (inches) | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 5 | 4 | 5 | 4 | 1 | — | 1 | 1 |
| No. of flounders | — | — | — | 1 | — | — | — | — |
| No. of dabs | — | 1 | — | 2 | 2 | 4 | 2 | 2 |

| Sizes (inches) | 9½ | 9¾ | 10 | 10¼ | 10½ | 10¾ | 11 | 11¼ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | — | 1 | — | — | 1 | — | — | — |
| No. of flounders | — | — | 1 | — | — | — | — | — |
| No. of dabs | 1 | — | 1 | 1 | — | 1 | 1 | 1 |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL20 | 7⅜ | 7 miles N.W. from Great Orme. | 5/11/06 | 9 | 8¾ | 1 | 1T |
| LL29 | 7½ | Off Great Ormes Head.. | 9/12/06 | 10 | 8½ | 1 | 1T |
| LL22 | 7¾ | Near Cordy Buoy, Dee... | 22/3/06 | 1 | — | — | 2T |
| LL5 | 9 Dab | Horse Channel, 10 faths. | 13/8/06 | 6 | 9 | — | 1T |
| LL11 | 8¾ Dab | Rock Channel, 3 faths.... | 11/8/06 | 6 | 9 | ¼ | 2T |
| LL37 | 7½ | Wallasey shore ..... | 26/4/06 | 2 | 7⅝ | ⅛ | SN |
| LL44 | 10¼ Flounder | Opposite Lytham, S. side Ribble. | 19/4/06 | 2 | 10¼ | — | B |
| LL19 | 8½ | Off old Pier, Morecambe | 26/11/06 | 9 | 9½ | ⅜ | 2T |
| LL32 | 8¼ | South Bay, Wexford, Ireland. | 16/5/06 | 2 | 8⅜ | ½ | 2T |

This experiment did not yield very notable results. None of the dabs or flounders liberated have been recovered so far, and the movements of the plaice which were recaught do not show any uniformity.

## Experiment 10, 12th June, 1906.

Station: Off Nelson Buoy.
Fish caught off Nelson Buoy.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) ..... | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10 | 10½ | 11½ | 11¾ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice ..... | 1 | 5 | 11 | 5 | 5 | 4 | 3 | 2 | 2 | 1 | 1 |

## Particulars of Fish Returned.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL171 | 10½ | Birkdale shore ..... | 12/6/06 | 1 | — | — | SN |
| LL193 | 9 | 1 mile N.W. from Nelson Buoy, 9 fathoms. | 3/9/06 | 3 | 10⅜ | 1⅜ | 2T |
| LL197 | 8½ | 1 mile S.W. from Nelson Buoy. | 20/9/06 | 3 | 9⅜ | 1⅛ | 2T |
| LL200 | 8¼ | 2 miles S.W. from Nelson Buoy. | 12/9/06 | 3 | 11½ | 3¼ | 2T |
| LL178 | 9¾ | Roosebeck, Morecambe Bay. | 23/10/06 | 5 | 11 | 1⅛ | 2T |
| LL167 | 11½ | 12 miles N. from Liverpool Bar Light Ship, 14 fathoms. | 15/7/06 | 1 | 11½ | — | 1T |
| LL169 | 10½ | Liverpool Bay, 14 faths. | 20/7/06 | 1 | 11⅜ | ¼ | 1T |
| LL177 | 9½ | Liverpool Bay, 17 faths. | 26/7/06 | 2 | 10½ | 1 | 1T |
| LL180 | 8¾ | 2 miles N.W. from Liverpool Bar Light Ship, 15 fathoms. | 2/8/06 | 2 | 9½ | ¾ | 1T |
| LL182 | 9 | 6 miles N.N.W. from Liverpool Bar Light Ship, 3 fathoms. | 8/11/06 | 5 | 11⅝ | 2⅝ | 1T |
| LL189 | 9 | "Meols Bay," 14 faths. | 13/7/06 | 1 | 9¼ | ¼ | 1T |
| LL191 | 8¾ | 12 miles N. from Liverpool Bar Light Ship, 14 fathoms. | 16/7/06 | 1 | — | — | 1T |
| LL201 | 9¼ | 20 miles N.W. from Liverpool Bar Light Ship, 19 fathoms. | 30/7/06 | 2 | 9½ | — | 1T |
| LL166 | 9½ | 10 miles N.N.E. from Morecambe Bay Light Ship. | 11/8/06 | 2 | 10¼ | ¾ | 1T |
| LL173 | 10 | 6 miles S.S.W. from Morecambe Bay Light Ship. | 30/6/06 | 1 | 10 | — | 1T |
| LL176 | 9¼ | 10 miles S.W. from Morecambe Bay Light Ship. | 26/10/06 | 5 | 10½ | 1⅛ | 1T |
| LL181 | 9 | 7 miles S.W. from Morecambe Bay Light Ship. | 2/8/06 | 2 | 10 | 1 | 1T |
| LL195 | 8¾ | 6 miles N.E. from Morecambe Bay Light Ship. | 11/8/06 | 2 | 9 | ⅛ | 1T |
| LL199 | 8¾ | 7 miles S.W. from Morecambe Bay Light Ship. | 14/7/06 | 1 | 9⅝ | ⅞ | 1T |
| LL202 | 8¾ | "Morecambe Bay," 20 fathoms. | 25/7/06 | 1 | 9⅝ | ⅞ | 1T |
| LL203 | 8¾ | 12 miles S.S.E. from Maughold Head, 12 fathoms. | 29/11/06 | 6 | 10⅞ | 2⅛ | ST |

## Experiment 15, 9th July, 1906.

Station: 5 miles N. from Liverpool Bar Lightship.
Fish caught near Nelson Buoy.

### Analysis of Sizes of Fish Liberated.

| Sizes (inches) | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10 | 10¼ | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 7 | 8 | 11 | 5 | 6 | 3 | 2 | 3 | 2 | 1 | 1 |

### Particulars of Fish Returned.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL254 | 10 | 7 miles (?) E. from Nelson Buoy. 7 fathoms. | 29/7/06 | 1 | 10 | — | 1T |
| LL257 | 9¼ | Off Nelson Buoy, 9 faths. | 11/9/06 | 2 | 9¾ | ½ | 2T |
| LL260 | 9¼ | Off Nelson Buoy, 13 fathoms. | 28/9/06 | 3 | 10½ | 1¼ | 1T |
| LL291 | 8¼ | 1½ miles S.W. from Nelson Buoy, 9½ faths. | 13/9/06 | 2 | 9 | ¾ | 2T |
| LL258 | 8½ | N.N.W. from Liverpool Bar Light Ship, 17 fathoms. | 14/8/06 | 1 | 8⅝ | ½ | 1T |
| LL270 | 8¾ | Pillar Buoy, Horse Channel, 9 fathoms. | 3/8/06 | 1 | 8¾ | — | 2T |
| LL272 | 8¾ | Liverpool Bay, 14 faths. | 24/7/06 | 1 | 8¾ | — | 1T |
| LL277 | 8½ | 16 miles N.N.W. from Liverpool Bar Light Ship, 17 fathoms. | 28/10/06 | 4 | — | — | 1T |
| LL282 | 8¾ | 12 miles S.S.W. from Morecambe Bay Light Ship. | 5/11/06 | 4 | 10¾ | 2 | 1T |
| LL288 | 8¾ | 5 miles N.E. from Liverpool N.W. Light Ship, 15 fathoms. | 8/9/06 | 2 | 9¼ | ½ | 1T |

Both Experiments 10 and 15 have given good results, the former shewing 50 per cent. and the latter 20 per cent. of recaptures. They may conveniently be considered together, as the fish were caught on the same ground; the stations of liberation are close together, and there was only a month between dates of the two experiments.

Bearing in mind that the fishes were liberated at about the time of midsummer, we should expect to find, if the results of the experiments already discussed hold good, that an offshore migration would be exhibited. A glance at Chart IV., where the positions of recaptures are roughly plotted, will shew that these experiments do, indeed, confirm the results already obtained. Most of the fishes returned were recaptured during the three months following liberation, that is during the time when we should expect to find the offshore migration in progress. It will be seen that there is practically no alongshore or inshore migration. Only three fishes have entered the territorial waters. No. LL171, from Experiment 10, immediately on being liberated hurried off inshore, and was caught on the same day in a stake net on Birkdale shore. No. LL270, from Experiment 15, also travelled inshore, and was recaught at the entrance to Horse Channel by a second-class trawler. Finally No. LL178, from Experiment 10, went inshore, and was caught off Roosebeck by a second-class trawler. But, with these exceptions, there is a well-marked offshore migration to be observed, the majority of the fishes returned being recaught to the West of the place of liberation, Nelson Buoy. Only one, No. LL203, went far afield, and was recaught by a Douglas steam trawler S.S.E. from Maughold Head. So far as has yet been observed, none of these fishes has made the lengthy migrations of which several instances have been noticed.

Experiment 11, 13th June, 1906.

Station: Off Pwllheli beach, Tremadoc Bay.

Fish caught off Pwllheli beach and off St. Tudwall Islands.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 |
|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 2 | 3 | 3 | 7 | 4 | 4 |
| No. of flounders | — | — | — | — | — | — | — |

| Sizes (inches) | 9¼ | 9¾ | 10 | 10¼ | 10½ | 10¾ | 11 |
|---|---|---|---|---|---|---|---|
| No. of plaice | 3 | 3 | 5 | 1 | 2 | 1 | 1 |
| No. of flounders | 1 | — | — | — | — | — | — |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL217 | 8¾ | Gimlet Rock, bearing N.W., distant 7 miles, Tremadoc Bay. | 19/7/06 | 1 | 9½ | ¾ | 1T |
| LL214 | 9¾ | 9 miles off the Bailey Light Ship, Dublin Bay, 16 fathoms. | 16/10/06 | 5 | 10¾ | 1 | — |

## Experiment 16, 12th July, 1906.

Station: Off Penkilan.

Fish caught off Penkilan.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 7 | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 1 | 1 | 7 | 7 | 9 | 4 | 9 | 3 | 6 | 1 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL422 | 9¾ | 2 miles S.W. from Jumbo Buoy, Ribble, 7 faths. | 4/10/06 | 3 | 10½ | ¾ | 2T |
| LL389 | 8 | Red Wharf Bay, 13 faths. | 9/12/06 | 6 | 8½ | ½ | 1T |

Experiments 11 and 16 may be considered together, since the times and stations of liberation were much the same. Neither experiment has, apparently, been successful. Last year (1905) several marked plaice were recaught in Tremadoc Bay, and it was thought desirable to fish there and mark a number of fish during the last summer. Accordingly 91 plaice caught near Pwllheli were liberated in June and July, but so far only four of these have been returned. One, No. LL217, was recaught in almost the same place where liberated, but the other three have made rather long journeys. One was caught in Dublin Bay about five months afterwards, having crossed the deep water of the Irish Channel, and two came North into Lancashire waters, one being recaught in Red Wharf Bay and the other in the Ribble Estuary. These two latter cases and another are the only instances noticed so far of plaice coming North from the Welsh Bays into Liverpool Bay, though the reverse migration has been observed many times already.

This paucity of recaptures is not to be attributed to the fact that the amount of fishing in Cardigan Bay has been less than usual. Capt. David Pritchard, the Head Bailiff at Pwllheli, writes me as follows:—"In my opinion, plaice have shifted for a time from the usual fishing ground in Tremadoc and Cardigan Bays. Our fleet of 15 small trawlers have been fishing at Tremadoc Bay and at Kilan Grounds, and only one marked plaice has been landed here. It is true that there were only two Southport trawlers in our bay last summer (1906), as against 22 the year before, but the plaice, turbot and brill were very scarce last summer (1906). There have been several large trawlers at work in Cardigan Bay during the last two months, landing their fish at Pwllheli, but a very small quantity of plaice were

landed here, and no marked ones. There has been a fair percentage of soles, but hardly any plaice to compare with former years."

I think, then, the cause of the apparent failure of these experiments is that a dispersal of the plaice present in Tremadoc Bay in June and July has taken place.

Experiment 12, 14th June, 1906.

Station: 2½ miles off Llanrhystyd.

Fish caught from New Quay to Aberaron.

Analysis of Sizes of Fish Liberated.

| Sizes (inches) | 7¼ | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 2 | 3 | 4 | 4 | 5 | 1 | 4 | 4 | 5 |
| No. of brill | — | — | — | — | — | — | — | — | — | — |
| No. of dabs | — | — | — | — | — | — | — | — | — | 1 |

| Sizes (inches) | 9¾ | 10 | 10¼ | 10¾ | 11 | 11¼ | 11½ | 11¾ | 12½ | 12¾ |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 5 | 2 | 1 | 1 | 2 | 1 | 1 | — | — | — |
| No. of brill | — | — | — | — | 1 | — | — | — | 2 | 1 |
| No. of dabs | — | — | — | — | — | — | — | — | — | — |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL249 | 11 | Off Llanrhystyd | 11/9/06 | 3 | 11¼ | ¼ | 2T |
| LL329 | 8¼ | Between Aberystwyth and Llanon, ½ mile from shore. | 24/7/06 | 2 | 9 | ¾ | 2T |
| LL335 | 9 | Near Llanon | 29/7/06 | 2 | 9½ | ¼ | 2T |
| LL338 | 7¾ | Near Llanon | 19/6/06 | 1 | 7¾ | — | 1T |

It will be seen that the plaice recovered from this experiment were all caught quite near to the place where liberated and within the territorial waters. One was recaught by the Aberystwyth first class trawler AB71, and the others by the Southport second class trawler LL343.

## Experiment 14, 16th June, 1906.

**Station: Ynys Fach, Cardigan Bay.**
**Fish caught off Aberporth Bay.**

ANALYSIS OF SIZES OF FISH LIBERATED.

| Size (inches) | 7½ | 7¾ | 8 | 8½ | 9 | 9¼ | 9¾ | 10 | 13 |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 2 | 4 | 1 | 2 | 1 | 1 | 3 | 1 |
| No. of dabs | — | — | — | — | 1 | — | — | — | — |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL378 | 8½ | Newport Bay ..... | 17/7/06 | 1 | 8⅞ | ⅜ | 1T |

## Experiment 13, 16th June, 1906.

**Station: 2 miles E.N.E. from Dinas Head.**
**Fish caught off Dinas Head.**

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 8¼ | 9 | 10¾ | 11 | 11¼ | 12 | 12¼ | 12½ | 12¾ | 13 | 13¾ | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 1 | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 3 | 2 | 1 |

PARTICULARS OF FISH RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL359 | 12 | Off New Quay Head, Cardigan Bay. | 23/10/06 | 5 | 12 | — | 1T |
| LL350 | 12½ | Milford Haven, Close to Milford Pier. | 1/11/06 | 1 | 13⅜ | 1½ | 2T |
| LL361 | 12¾ | 9 miles S.W. from South Bishop. | 18/11/06 | 6 | — | — | ST |

**Experiments 13 and 14 were made in the Milford Haven Sea Fishery District during a police visit to those**

waters by the "John Fell." It was intended to carry out a somewhat extensive fish-marking experiment on this cruise, but a report of poaching by a steam trawler (which was detected) compelled Capt. Wignall to change our proposed plans.

The recaptures reported shew no unusual features. They were mostly made South of the places of liberation. Fishing there is, of course, more extensive than to the immediate North.

### Experiment 17, 19th September, 1906.

Station: Red Wharf Bay.

Fish caught in Red Wharf Bay.

ANALYSIS OF SIZES OF FISH LIBERATED.

| Sizes (inches) | 7 | 7¼ | 8 | 8½ | 8½ | 9 | 9¼ | 9¾ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 2 | 1 | 3 | 6 | 3 | 3 | 1 |

| Sizes (inches) | 10 | 10¼ | 10½ | 10¾ | 11 | 11¼ | 11½ | 13½ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 8 | 1 | 2 | 1 | 2 | 4 | 1 | 2 |

PARTICULARS OF FISH RETURNED.

| 1 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL439 | 13½ | Off Great Ormes Head, 5 fathoms. | 29/9/06 | 1 | 13½ | — | 2T |
| LL451 | 11 | Red Wharf Bay, 12 faths. | 11/12/06 | 3 | 11¼ | ¼ | 1T |
| LL454 | 10 | Red Wharf Bay, 12 faths. | 25/11/06 | 2 | — | — | 1T |
| LL460 | 10 | Red Wharf Bay, 6-7 faths. | 7/10/06 | 1 | 10 | — | 1T |
| LL467 | 8¼ | Red Wharf Bay, 7 faths. | 7/10/06 | 1 | 8¼ | — | 1T |
| LL474 | 8¼ | Red Wharf Bay..... | 9/10/06 | 1 | 8¼ | — | 1T |
| LL475 | 8 | Mostyn Deep. Dee ..... | 23/10/06 | 1 | 8¼ | ¼ | 2T |
| LL477 | 8¼ | 4 miles N. from Puffin Island. | 23/10/06 | 1 | 8½ | ¼ | 1T |

It will be seen that quite a number of recaptures were made shortly after the date of this experiment. I expected that a large proportion of these fishes would be recaught, but after the second month none has been caught. The cause is probably the wild weather of November and December, which has not only affected the fishing, but has also probably led to considerable shifting of the fishes normally present on the fishing grounds. We find that heavy gales have this effect on the shallow water fishing grounds on the West Coast of England.

Experiment 18, 3rd October, 1906.

Station: Luce Bay.

Fish caught in Luce Bay.

Analysis of Sizes of Fish Liberated.

| Sizes (inches) | 8½ | 9¼ | 11¼ | 11½ | 11¾ | 12 | 12¼ |
|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 1 | 1 | 1 | 1 | 5 | 4 |

| Sizes (inches) | 12½ | 12¾ | 13 | 13¼ | 13½ | 13¾ | 14 |
|---|---|---|---|---|---|---|---|
| No. of plaice | 5 | 2 | 10 | 8 | 9 | 1 | 1 |

Particulars of Fish Caught.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL506 | 12¾ | Luce Bay, off Chapelrossen, 6 fathoms. | 11/10/06 | 1 | 12¾ | — | GN |

This experiment was made while trawling in Luce Bay for spawning plaice for Piel Hatchery.

## Intensity of Fishing.

The Summary Table shews that about 19 per cent. of the plaice and 19 per cent. of all the fishes liberated during the year have been recovered. Of course, several of the experiments were made late in the season, and many more recaptures will doubtless be made. A considerable number of dabs were also marked and liberated, and these have given poor results. The individual experiments vary greatly in their numerical results. Experiment 10, for instance, gives 50 per cent. of returns for six months' fishing only, while Experiment 7 for nine months' fishing gives only 9 per cent. of recaptures. Many factors influence the numerical result of these fish-marking experiments. In Experiment 10 the fish had not apparently become widely dispersed, and were, moreover, liberated at a place which is situated near the widely-frequented fishing ground lying between Liverpool North-West and Morecambe Bay Lightships. Experiment 7 failed probably because the fish marked were in poor condition, and had not been able to survive the transference from tank to tank and the subsequent marking operation. Again, Experiments 11 and 16 were apparently unsuccessful because, for some reason or other, the fish marked have probably become widely dispersed, possibly into areas where there is at present little or no plaice fishing being carried on.

Premising, then, that by "Intensity of fishing" is meant only a very rough approximation to the extent to which the plaice population of the West English seaboard is being exploited, and that for even an approximate estimate of this value much more extensive marking experiments than we have made would be required, I give the figures in the last column of the Summary as representing these approximations.

### Influence of Different Kinds of Fishing.

It was not always possible to obtain information as to the method of fishing by means of which the marked fishes were recaught. The following list has been compiled from the tables of particulars of fish recaught:—

| Method of Fishing. | No. of Marked Fish Returned. |
|---|---|
| 1st class sailing trawlers | 64 |
| 2nd class sailing trawlers | 37 |
| Stake nets | 23 |
| Steam trawlers | 16 |
| Baulks | 7 |
| Gill nets | 7 |
| "Set nets," "trammels," "tees," lines, salmon nets. | 5 |
| Information not given. | 8 |

It will be noticed that fishing by means of first class trawlers (smacks) apparently predominates in the "home grounds" of the Irish Sea. The proportions between the various methods of fishing by means of which the marked fishes have been recaught are almost exactly those compiled from the experiments of 1905.

### Rate of Growth of Plaice in the Irish Sea.

In attempting to deduce the rate of growth of plaice from the marking experiments, two series of figures are made use of—(1) those indicating the increase in length of the marked fish which were set free before the beginning of the season during which growth takes place, that is April-September. The defect in this series is the small number of recaptures during the latter half of the year. It has been found during the two last years that even if a fairly large number of marked fishes have been liberated before the end of March, quite a small proportion will be recaught during the autumn and winter. One

cause is probably the decrease in the intensity of the plaice-fishery during the months of September-December. Marked plaice are usually recaught by sailing trawlers, and the unfavourable weather usually experienced during October to December is prejudicial to the fishery. It will be seen from the statistics of plaice landed in the Lancashire and Western Fisheries District that there is an undoubted falling off in the intensity of the plaice fishery during those months. Consequently, fewer marked fishes are recaught.

The following table is compiled from the results of the experiments of 1905 and 1906:—

RATE OF GROWTH OF MARKED FISHES FROM MONTH TO MONTH.

| Month. | No. of Fishes Recaught. | Average Increase in Length. |
|---|---|---|
| January | 45 | 0·04 inches (0·1 cm.) |
| February | 22 | 0·04 ,, (0·1 cm. |
| March | 15 | 0·17 ,, (0·4 cm.) |
| April | 21 | 0·22 ,, (0·5 cm.) |
| May | 27 | 0·53 ,, (1·34 cm.) |
| June | 18 | 0·92 ,, (2·35 cm.) |
| July | 24 | 1·7 ,, (4·33 cm.) |
| August | 16 | 1·7 ,, (4·33 cm.) |
| September | 13 | 2·44 ,, (6·12 cm.) |
| October | 3 | 2·4 ,, (6·12 cm.) |
| November | 7 | 2·37 ,, (6·1 cm). |
| December | — | — — |

The results are represented graphically in Fig. 8.

It will be seen from the table and chart that the growth during January, February and March is practically *nil*. Indeed, the months October, November and December are also to be included, since a large number of the fishes included in the table for January were liberated in the preceding October and November of both years, and some were recaught during those months.

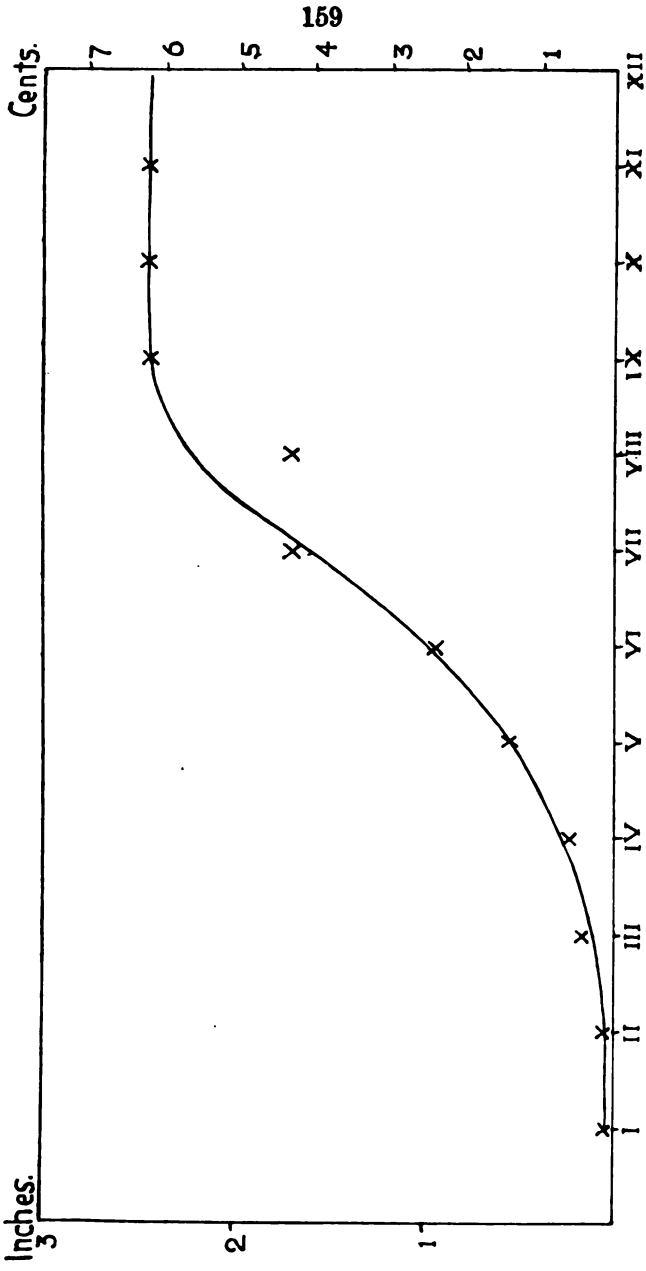



Fig. 8. Curve of growth of marked plaice.

It was only in a very few cases that any increase in length was detected in fishes liberated during October-December and recaught in January. In April the season's growth begins, and this is most rapid during the months June, July and August. It will be seen that the increase in length during August was apparently *nil*. That is the average length of the marked fishes returned during that month (and which had been in the sea during the whole season) was apparently no greater than those returned during July. I am quite certain, however, that this is only apparent, and that the fishes received in the laboratory during August were uniformly under-measured. The measurements were made by a laboratory assistant during my absence. It is, indeed, not usually a simple affair to measure a marked plaice sent by post. The fish is often dry, and has to be relaxed by immersion in water for some hours. Then a dead plaice is always shorter than a living one (probably because of the contraction or compression of the inter-vertebral discs). This can be corrected by slightly stretching the fish, and the contraction usually varies from 0·5 to 1 cm. according to the size of the fish.

It is, however, quite legitimate to "smooth" the curve, which then shows what is probably a little less than the normal rate of increase in length of plaice from month to month throughout the year. In October growth practically ceases. Plaice during the months of November-January usually have very little food in their stomachs, and many are entirely empty during December and January. During those months the weight of the fish decreases. Altogether the metabolism of the animal is greatly lessened.

The annual rate of increase in length as shewn by the curve is, therefore, about $2\frac{1}{2}$ inches. The annual

growth has, however, been measured in another way. Quite a number of marked plaice have been recovered which have experienced a whole season's growth, regarding the growth season as ending at the end of September, and the particulars of growth of these are tabulated as follows:—

PARTICULARS OF FISHES WHICH HAVE UNDERGONE ONE OR MORE COMPLETE SEASONS' GROWTH.

| | Date when liberated. | Date when recaught. | Increase in size (inches). |
|---|---|---|---|
| L104 | 12/11/04 | 12/11/06 | 7·25 (2 seasons' growth). |
| L152 | 12/11/04 | 3/12/05 | 5·25 |
| L242 | 18/11/04 | 7/2/06 | 4·5 |
| L252 | 18/11/04 | 28/2/06 | 1·5 |
| L287 | 18/11/04 | 12/11/06 | 6·25 (2 seasons' growth). |
| L288 | 18/11/04 | 4/9/06 | 6·5 (nearly 2 seasons' growth). |
| L294 | 18/11/04 | 3/10/05 | 1·75 |
| L341 | 13/11/04 | 28/10/05 | 2·75 |
| L345 | 13/11/04 | 3/11/05 | 3·5 |
| L444 | 21/1/05 | 19/10/05 | 3·62 |
| L505 | 17/3/05 | 7/12/05 | 2·25 |
| L522 | 17/3/05 | 16/11/05 | 3·0 |
| L528 | 6/7/05 | 10/7/06 | 4·0 |
| L541 | 6/7/05 | 17/9/06 | 5·75 (over 1 season's growth). |
| L587 | 12/7/05 | 7/7/06 | 1·75 |
| L713 | 1/2/06 | 21/9/06 | 2 |
| L716 | 1/2/06 | 13/11/06 | 3·0 |
| L721 | 1/2/06 | 30/9/06 | 2·75 |
| L760 | 19/2/06 | 28/11/06 | 3·11 |
| L762 | 19/2/06 | 28/11/06 | 2·85 |
| L848 | 22/7/05 | 26/9/06 | 3·3 |
| L904 | 26/10/05 | 26/9/06 | 3·25 |
| L938 | 26/10/05 | 27/9/06 | 2·5 |
| LL19 | 6/3/06 | 26/11/06 | 0·75 |
| LL20 | 6/3/06 | 5/11/06 | 1·0 |
| LL29 | 6/3/06 | 9/12/06 | 1 |
| LL104 | 31/3/06 | 23/11/06 | 2·25 |

**Average: 3·01 inches (= 7·6 cms.).**

Several fishes exhibiting a complete season's growth have been received since the above table was compiled. The results do not, however, alter the general growth rate already deduced.

Twenty-seven fishes are represented, and this is

probably a sufficient number to yield a fair average. In calculating this, however, the total increase has been divided by 29 instead of 27, since two of the fishes have undergone two seasons' growth. One has slightly over one season's growth, but this may be neglected. The average thus obtained is almost exactly three inches.

This is rather more than the result given by the former table, but it must be remembered that the latter probably under-estimates the rate of growth. If a larger number of marked fishes had been recovered in September-November, the growth would no doubt have been greater. But it is also probable that the results of the second table slightly over-estimate the year's growth. The fishes represented have all been in the sea for over the average length of time between marking and recapture. They are, therefore, probably more vigorous fish than the others, and may have grown more rapidly. Their average initial length was also a little more than the others.

At any rate the difference is not great, and one may conclude that in the Irish Sea plaice grow about $2\frac{3}{4}$ inches in the year. This applies to fish which are initially of the ordinary smaller marketable sizes, viz., 8 to 10 inches.

It should be noted, too, that considerable variation in growth rate exists. Thus plaice No. LL19, after a whole season's growth, had increased only $\frac{3}{4}$-inch in length. On the other hand plaice No. L152, after a season's growth, had increased in length $5\frac{1}{4}$ inches. Both cases are of course extremes, and are quite abnormal.

The otoliths, or earstones, of about half the marked plaice recovered have been examined, with the object of determining the ages of the fishes. It is well known that the calcareous matter in these structures is laid down regularly, so that every year after the first, two distinct

rings an opaque zone and a translucent zone are added to the otolith. By counting the number of opaque rings, it it possible to arrange the fishes in the groups O, I., II., III. and IV. according to the number of these zones outside the dark nucleus of the otolith. Of the total number of marked plaice returned 66 have been examined in this way, and may be grouped as follows:—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| O | Group | (in the | first | year | of | life)... | ... | 0· |
| I. | ,, | ( ,, | second | ,, | ,, | )... | ... | 3 |
| II. | ,, | ( ,, | third | ,, | ,, | )... | ... | 34 |
| III. | ,, | ( ,, | fourth | ,, | ,, | )... | ... | 22 |
| IV. | ,, | ( ,, | fifth | ,, | ,, | )... | ... | 12 |

The numbers examined are, of course, much too small to enable a satisfactory estimate of the size of the fishes at each year to be made. I give the averages calculated for what they are worth:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Females | in | Group | II., | average | length | = 9·3 | inches. |
| ,, | | ,, | III., | ,, | ,, | = 12·2 | ,, |
| ,, | | ,, | IV., | ,, | ,, | = 14 | ,, |

## Fish Caught in Extra-Territorial and Intra-Territorial Waters.

There were almost exactly as many marked fish recaught outside as in the territorial waters. Such a statement possesses, however, no significance since, if it is the case that an offshore migration takes place in the summer months and an inshore and alongshore migration in the winter months, it obviously follows that the numbers of marked fishes caught inside and outside the territorial limits depends on the time of year at which most of the marked fishes were liberated. If we mean by "winter" the months October to March, and by "summer" the months April to September, we then

find that 613 plaice were liberated in the "winter" months of 1904-5, and 217 were liberated during the "summer" months. During the year 1905 about 72 per cent. of the fishes recovered were recaught within territorial waters, and about 28 per cent. were caught outside the territorial limits. Thus the result of these experiments, in which nearly three times as many fishes were liberated during the winter months as during the summer, is that nearly three times as many fish were caught within the territorial as without. On the other hand, in 1905-6, 290 plaice and flounders were liberated in the winter months and 354 plaice and flounders in the summer months, and we find that in these experiments, when the liberations during the two seasons were not far from being equal in number, the number of fishes recaught outside is very nearly equal to those recaught inside the territorial waters.

With regard to the size of the fishes recaught, these have not so far been tabulated so as to bring out any relation between depth of water and length of fish. It will be better to let these observations accumulate, and then make this analysis when quite a large number of marked fishes have been recovered. Generally speaking, fishes which at the time of marking and liberation were the largest have travelled furthest. Large fishes have, of course, more vitality, and it is undoubtedly the case (with certain well-known exceptions) that the plaice caught outside territorial waters are larger on the average than those caught inside. But as regards the proportion of fishes caught inside as compared with those caught outside the technical territorial water limit, the main factor is the opposing offshore and inshore migrations, which depend more on the seasons than on the mere size of the plaice.

## General Conclusions.

### 1.—Percentage of fish recovered.

This, as the Summary Table shews, varies from 50 per cent. to 4 per cent. in the case of plaice, taking each experiment by itself. The causes of the difference in the percentage of fishes recorded are (1) the intensity of fishing, as for example in the case of Experiment 10, where an active fishery was carried on during the summer months over the area immediately contiguous to the place of liberation; (2) on the method of dispersal of the marked fishes, as for instance in Experiments 11 and 16, where the marked fishes liberated have probably been widely dispersed into areas where little trawl fishing is carried on; and (3) on the vitality of the marked fishes, as for instance in Experiment 5, where (as in the case of Experiment 12 of 1905) plaice were marked which had been for many months kept in tanks, and were in poor condition.

### 2.—Influence of methods of fishing.

First-class sailing trawlers have recaught more marked plaice than any other class of vessel or fishing method. There is little doubt that in the Lancashire and North Welsh Fishing Grounds this method of trawling predominates, at least for the "home waters." The steam trawlers have caught fewer fishes, but it is well known that these vessels go much further afield and do not frequent the grounds where the marked fishes may be expected to be recaught to the same extent that the smacks do.

### 3.—Rate of growth.

The estimates of the rate of growth of marked fishes constructed on the results of the experiments of 1906 agree

well with those of 1905. Plaice practically do not grow at all during the months October to March. At the end of the latter month growth begins. During the months noted, any apparent increase in size of the plaice returned is probably due as much to errors in measurement as to actual growth. At the end of March we begin to notice an increase in length, and during April, May and June the fish steadily increase in length. During July and August the growth is most rapid, and during September it begins to fall off, and in October the plaice have ceased to grow. An estimate of the rate of growth based on the study of a curve constructed from these monthly increments of growth gives us a value of about $2\frac{1}{2}$ inches (6·3 centimetres) as the yearly growth rate of the plaice in the waters of the Irish Sea East of the Isle of Man and adjoining the coasts of Lancashire, Cheshire and North Wales.

But when the increments of growth indicated by the fishes which have been recovered after one or more years' sojourn in the sea are tabulated, the average growth rate works out at almost exactly 3 inches (7·6 centimetres). A sufficient number of fishes have been recaught, after being about a year in the sea, to render this estimate a very probable one. At the same time it should be noted that these are the larger and more vigorous fishes (as is indicated by their more lengthy migrations), and that they, therefore, grow perhaps more rapidly than the others which have remained closer to their original habitats.

The cessation of growth in the colder months of the year is not necessarily connected in any way with the spawning habits of the fishes. The great majority of the marked fishes recaptured were immature fishes, and one cannot, therefore, attribute the cessation in growth in the

winter to the maturation of the reproductive organs. There is undoubtedly a decrease in the metabolism of the fish during the cold weather. It does not feed, or does so to a very slight extent, during the months of December and January, and the weight of a plaice of a certain length is always less in the winter than the weight of a fish of the same length in the summer.

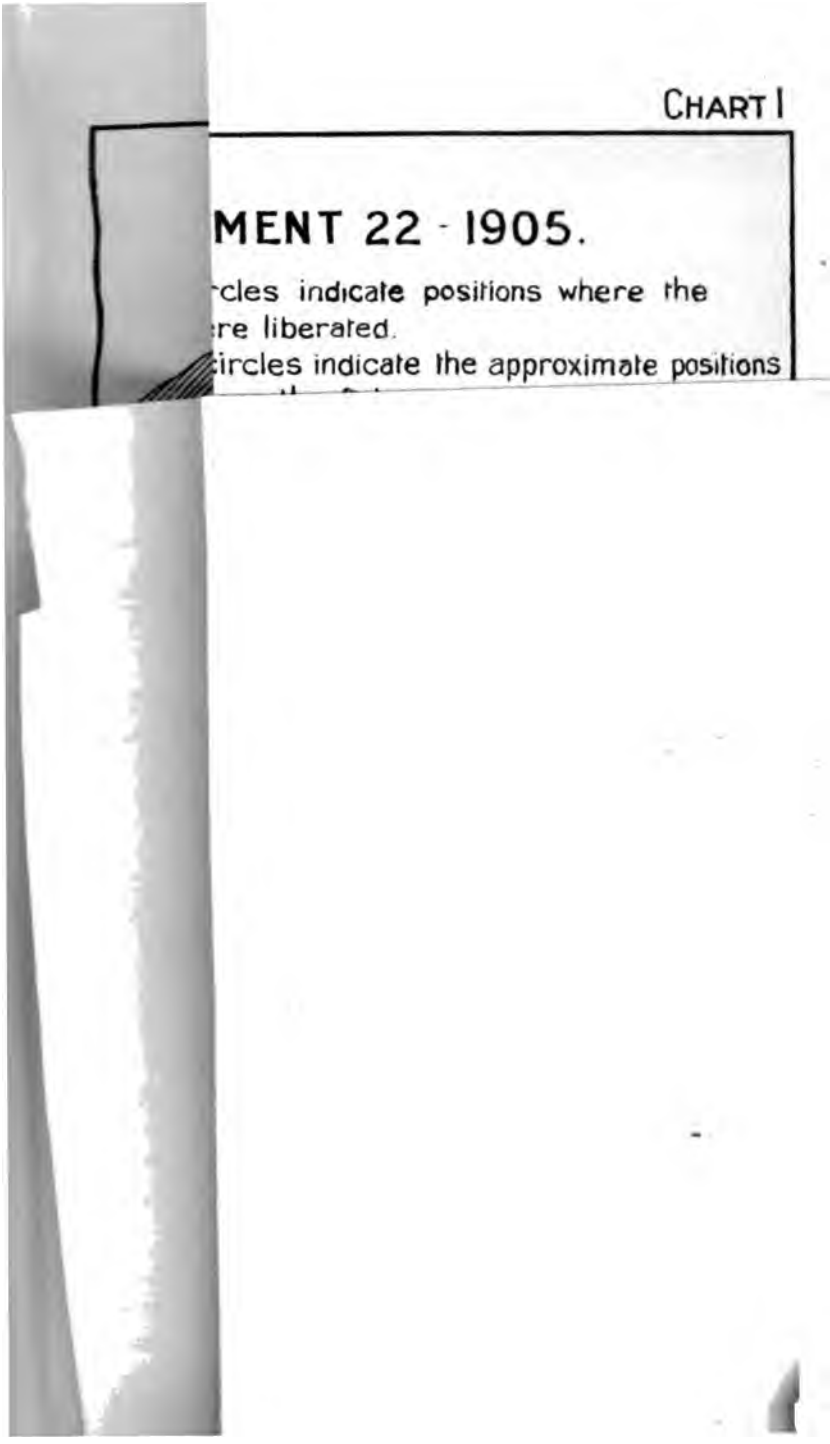
### 4.—The migrations.

It should be noticed that many instances of quite exceptional migrations are recorded in the tables. Thus fishes liberated off the coast of Lancashire have been recaptured off the East and South Coasts of Ireland, and fishes liberated in the same area have also been recaught at the mouth of the Bristol Channel. These lengthy migrations would not surprise us if they were made by actively growing fishes like the cod or hake, or pelagic fishes like the mackerel, but one is accustomed to speak of the plaice as a semi-sedentary fish. Leaving aside these exceptional migrations, the results of this and last year's experiments shew with some probability that plaice in our waters do not move about in the winter to the same extent that they do in the summer, and that the winter migrations are mostly alongshore ones, with perhaps a general trend to the North along the coasts of Cheshire and Lancashire. In the summer, on the other hand, the migration is an offshore one. There are evidences of a tendency to the southward, and in the exceptionally lengthy migrations already referred to, it is generally this southerly migration that is made. While plaice have been observed to travel from the coasts of Lancashire and North Wales into Tremadoc and Cardigan Bays, the opposite migration has only been observed in two instances.

It should also be noted that plaice are not of necessity restricted to comparatively shallow waters. The opinion of most fishermen and others is that outside the 20-fathom contour line plaice are hardly to be found, and no doubt this is largely true. But the fish does migrate, at least, through waters of much greater depth than this, for we have found that they may cross the Irish Channel, which nowhere has a depth of less than about 50 fathoms, and one plaice (L541, Experiment 14, 1905) was actually caught by a steam trawler in water of 57 fathoms W.S.W. from the Smalls Light.

Evidence that the marking operation, if carried out carefully on a vigorous plaice, has no effects which are prejudicial to the normal movements and growth of the fish is afforded by several plaice which have been recaught after a considerable lapse of time. No. L104 was taken after exactly two years had elapsed since the time of liberation: this fish had grown $7\frac{1}{4}$ inches. No. L287, too, was recaptured after being almost exactly two years in the sea: it had grown $6\frac{1}{4}$ inches; and No. L288 was also retaken after very nearly the same interval, and was $6\frac{1}{2}$ inches larger than when marked. All these fishes passed through my hands, and their condition was that of normal well-nourished fishes, while the wound caused by the affixed mark was clean and not much larger than when initially made. Then quite a number of fishes have been returned after having been in the sea for periods of from 9 to 15 months, and with few exceptions normal rates of growth were exhibited.

CHART I



MENT 22 - 1905.

rcles indicate positions where the
re liberated.
circles indicate the approximate positions

CHART II

IMENTS 1,6.□ 2,3.○

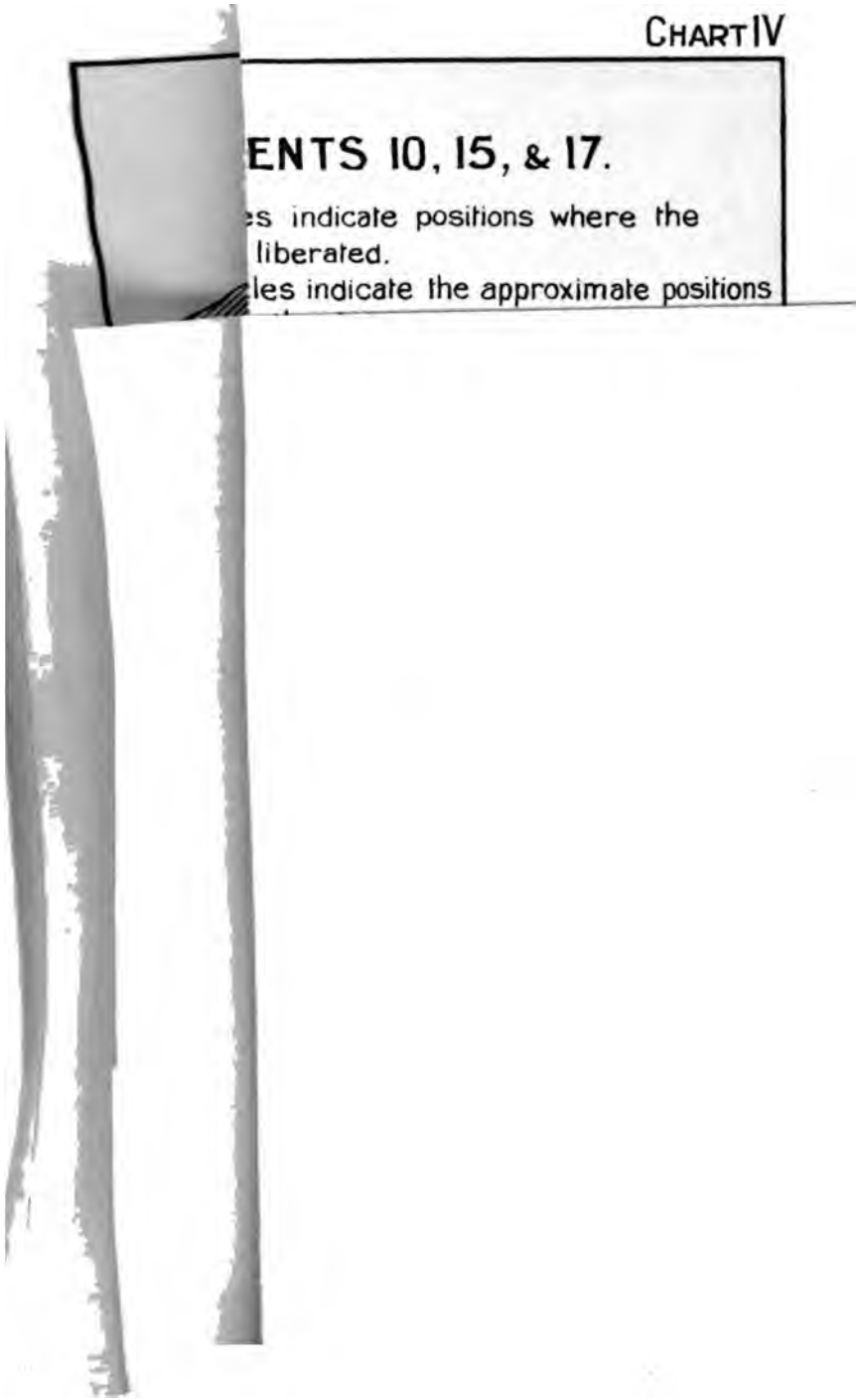
circles indicate positions where the
vere liberated.
circles indicate the approximate positions

CHART III

# MENTS 5,7,8,& 9.

rcles indicate positions where the
ere liberated.
circles indicate the approximate positions

CHART IV


ENTS 10, 15, & 17.
s indicate positions where the
liberated.
les indicate the approximate positions

## Explanation of the Charts.

The charts are to be regarded as exhibiting objective representations of the migrations of the fishes. Except in Chart I it has not been attempted to express synoptically these migrations. Probably the accumulation of several years' results will enable this to be done. In the meantime it is best to indicate the facts only.

The lines connecting the stations of liberation with the places of recovery do not, of course, necessarily indicate the migration paths.

It was often difficult to be sure of the exact position of recapture. Depth of water, for instance, as given on an Admiralty chart, often does not agree with the recorded position of recapture. It is perhaps nearly always the case that there may be an error of from one to several miles in the recorded place of recapture, since a fish may be caught at any point of a haul (which may be from 2 to 24 miles in length).

# INTERNAL PARASITES AND DISEASED CONDITIONS OF FISHES.

By JAS. JOHNSTONE.

1. CESTODA.
2. TREMATODA.
3. PROTOZOA.
4. CATARRHAL CONDITIONS IN DAB AND SALMON PARR.

## I.—CESTODA.

**Abothrium rugosum** (Goeze).

From *Gadus callarias*. This is *Bothriocephalus rugosus* (Goeze) Rudolphi = van Beneden's *Abothrium gadi*.

About a dozen large cod were dissected last winter, and this cestode was invariably found. Sometimes there were as many as a dozen large worms in each fish. The head of each cestode is implanted in a pyloric caecum, in such a manner that it is impossible to extricate it. I repeatedly dissected these structures with the greatest care, but was never able to find anything resembling a typical bothriocephaline scolex and I do not think that this structure exists in the mature stages of the worm. A portion of the anterior end of the strobila is buried up in a caecum and when the walls of the latter are picked away bit by bit with dissecting needles all that remains is a contorted, horny or waxy-looking, thick filament. The walls of the caecum undergo profound change and become semi-transparent and waxy, sometimes horny, in nature. Sometimes the anterior end of the cestode has perforated the lateral wall of the caecum and lies outside the latter as a contorted kind of cord. It is possible to pick away this investment and then the greatly con-

tracted strobila is seen inside, but without any trace of segmentation. As one attempts to dissect out the latter one finds that it gradually becomes fused with the surrounding waxy tissue which is probably derived from the caecum, and invariably the structure breaks. Von Linstow* describes the worm as having a pseudo-scolex with two slightly developed sucking grooves and figures such a head, from the intestine of *Lota vulgaris*, as a normal structure. Probably in young codling, recently infected, a stage of the cestode with such a scolex might be found but doubtless with increasing age the changes mentioned above occur, and the normal structure of the head disappears.

The lumen of the gut immediately behind the stomach may at times be almost blocked by the strobilae of these cestodes. The largest specimen found was 85 cm. in total length and about 8 mm. in breadth at its widest part. This worm was, however, incomplete. The older proglottides contained fully developed oncosphere larvae belonging to a later stage than Schauinsland's Fig. 8. (Bronn, Thier-reich, Bd. 4, 1 B, Pl. LVII, Fig. 8.) These larvae have a fully developed mantle. They are from 90 to 120 $\mu$ in diameter. The undeveloped eggs from the less ripe proglottides are much smaller, and are about 30 $\mu$ in diameter.

**Echinobothrium affine,** Diesing.

From *Raia clavata*, Shoals, 1906.

A single specimen of a small cestode, preserved from the contents of the spiral valve of a large thornback ray, appears to belong to this species. The worm, however, differs in certain respects from both *Echinobothrium typus* and *E. affine*. Fig. 9 represents the scolex, neck and the

* Arch. f. Naturgesch., 54 Jahrg. 1888, Bd. I.

first few proglottides, and Fig. 11 a part of the neck with some typical spines. Measurements from this single specimen are:—

FIG. 9. *Echinobothrium affine*, Diesing. Head and part of strobila. × 44 dia.

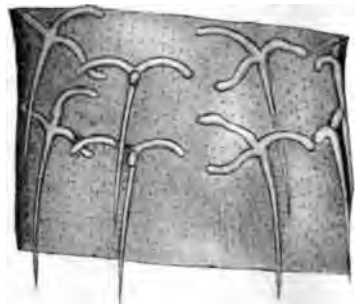


FIG. 10. *Echinobothrium affine*, Diesing. Spines on neck. × 300 dia.

Length of head: 1·3 mm.
Breadth of head: 0·36 mm.
Length of a spine from the neck: 0·1 mm.
Breadth of a spine from the neck: 0·05 mm.

A notable difference from the descriptions of either of the above specimens is the absence of coronal hooks. In both *E. typus* and *E. affine* there are two groups of long, slightly-curved hooks on the two muscular lobes of the scolex. In my specimen no trace of these was seen. I think it probable, however, that these spines, or hooks, have been lost in detaching the cestode from the walls of the intestine. Very distinct indications of a musculature which might easily serve for producing movements of the coronal spines are visible.

The neck is long and the spines there are well shown. Four longitudinal rows can be seen when the worm is slightly flattened out. These spines differ slightly, however, from the figures of van Beneden,* or Wagener.† The summit of each hook (Fig. 10 ) is triradiate, these transverse pieces being bent or slightly twisted. The shaft of the spine itself is very slightly curved.

**Calliobothrium eschrichtii,** van Beneden.

From *Mustelus vulgaris,* Llandudno Bay, 1906.

A small male *Mustelus* examined had numerous cestodes on the walls of the spiral valve. Each strobila was about 8 mm. to 1 cm. in total length and consisted of comparatively few (about half-a-dozen) proglottides. In addition to these strobilae there were very many detached proglottides in the lumen of the large bowel, most of which belonged presumably to the cestode referred to here. Measurements are:—

Length of strobila: 8 mm. to 10 mm.
Length of terminal proglottis: about 3·5 mm.
Length of first distinct proglottis: 0·6 mm.
Length of scolex: 1·2 mm.
Breadth of scolex: 1 mm.
Greatest length of hooks: 0·08 mm.

* Mem. sur les Vers Intestinaux, 1858; pl. 19.
† See Bronn's Thier-reich, Bd. 4, 1 B, Taf. xl., fig. 1.

The neck is very short. The whole strobila immediately breaks up on preservation in formalin.

Fig. 11B represents the scolex and fig. 11A a pair of hooks. I find the size and appearance of the accessory

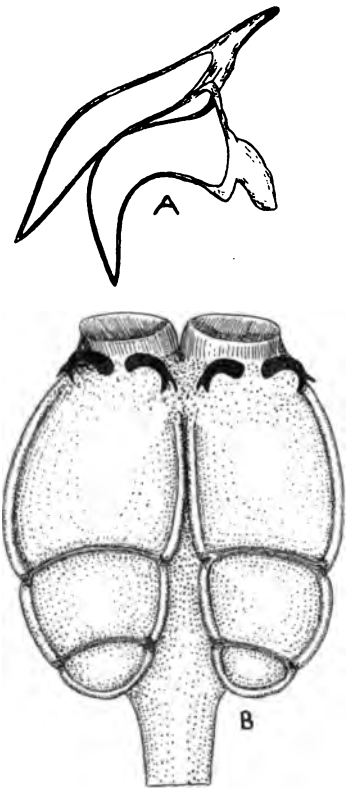



FIG. 11. *Calliobothrium eschrichtii*. A—Hooks, × 575; B—Scolex, × 45 dia.

sucker at the summit of the scolex differs somewhat from van Beneden's fig. *, but the precise appearance of cestode worms when preserved varies so much that the

* Fauna littorale de Belgique. Vers Cestoides, pl. xix.

differences are perhaps to be attributed to the action of the preservative. The hooks are large and very noticeable. They are not bifurcated, but lie in pairs with their broad bases in close contact. One is only slightly curved, but the other is strongly bent. Delicate focussing shews that these structures are hollow.

**Anthobothrium musteli,** van Beneden.*

From *Mustelus vulgaris*, Llandudno Bay, 1906.

About six specimens of a cestode which appears to be the above species were found in the large intestine of a small *Mustelus*. The characters differ slightly from those

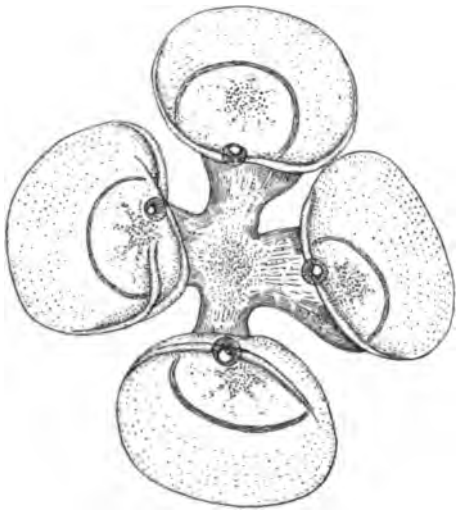


FIG. 12. *Anthobothrium musteli.* Scolex. × 46 dia.

given by van Beneden, so I add a description and figure. The measurements of the worm are:—

Length of longest strobila (incomplete): 32 mm.
Diameter of scolex: 1·3 mm.
Diameter of a bothrium: 1·3 mm.
Diameter of auxiliary sucker: 0·1 mm.
Length of a free proglottis: 6 mm.
Breadth of a free proglottis: 2·5 mm.

* Vers Cestoides, p. 126, pl. 7.

The scolex, which is represented in fig. 12 is large and very regular in shape, suggesting a four-petaled flower. There is no myzorhynchus. There are four long mobile pedicels, each of which carries a shallow cup-shaped bothrium—this is never trumpet-shaped. The internal margins of the bothria have thickened rims with a notch in the middle, but the external margins are very thin. On the internal margin of each bothrium is a small auxiliary sucker, which is not conspicuous and may easily be overlooked. In the centre of each bothrium is an irregular rosette-shaped patch, which appears to represent a radial arrangement of muscle bands, such as is represented in van Beneden's figure 3, but the precise disposition of the muscle bundles shown there does not appear in my specimens. Round this is an annular band of muscles.

**Tetrarhynchus erinaceus,** van Beneden.

An interesting addition to the intermediate hosts of this tapeworm is the Halibut, *Hippoglossus vulgaris.* Two specimens of pieces of halibut flesh were sent to this laboratory from the Board of Agriculture and Fisheries. In one case the flesh was abundantly infested with the plerocercoid larvae of the cestode, and in the other case a similar infection had taken place, but the larvae were restricted to the muscles round the vertebral column. The cysts containing larvae were ususually large, and were usually present in tubular cavities in the muscle tissue. Many larvae were in process of disintegration, and in some cases the cyst contained nothing but a mass of calcareous granules. Usually plerocercoid larvae of *T. erinaceus* are adherent to the peritoneum and projecting into the body cavity, and the general infection of the flesh is apparently a rare condition.

## 2.—TREMATODA.

**Distomum ocreatum,** Molin.

From stomach of *Conger vulgaris*; top end of "Hole" (nearly midway between Douglas and Fleetwood).

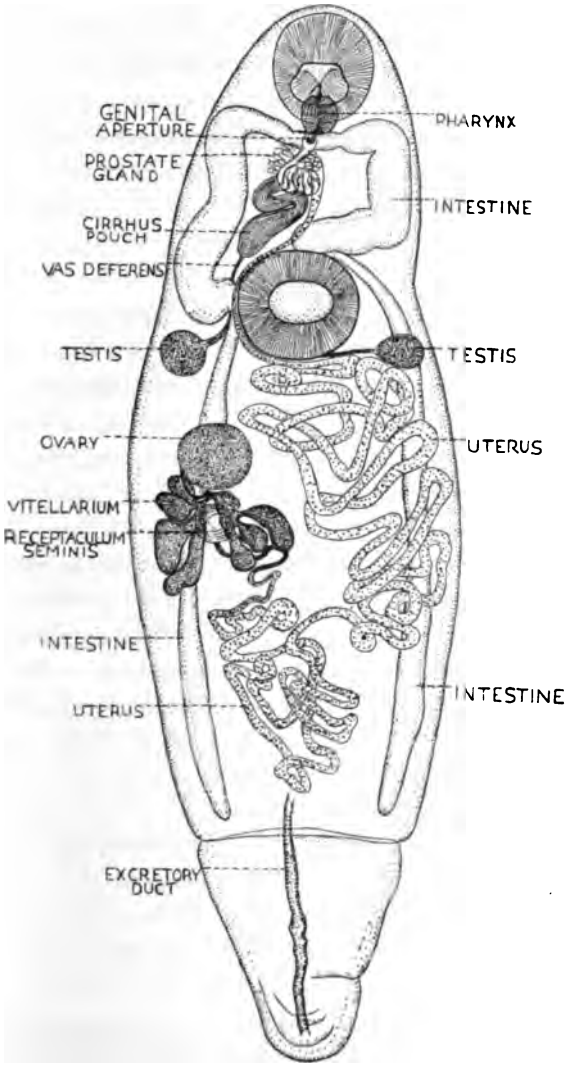



FIG. 13. *Distomum ocreatum.* × 18 dia.

In the caecal part of the stomach of a conger eel about five feet long over 100 specimens of this distomid were found. The worms while alive were blood-red in colour. The size was variable: when dead after killing in fresh water they were from 5 mm. to about 2·5 mm. in length. The anterior extremity in this state is usually bent ventrally towards the ventral sucker. The following measurements relate to a specimen which had been killed in an expanded condition by slight pressure between two glass slides.

Total length: 8 mm.
Greatest breadth: 2·25 mm.
Diameter of oral sucker: 0·88 mm.
Diameter of ventral sucker: 0·92 mm.
Diameters of ova: 0·024 × 0·013 mm.

The species is, doubtless, near *Distomum ocreatum* of Molin, but the characters of the appendiculate Distomids with suckers of nearly equal size do not appear to be very well marked, so I add the following description.

The suckers are very nearly equal in size, the ventral being usually only very slightly the larger of the two. The mouth is sub-terminal and lying very near to the pharynx. There is no distinct oesophagus and the intestine passes transversely across the body without any distinct fork. In life the rythmical movement of this transverse portion of the intestine is very well marked. Successive peristaltic movements pass outwards from the junction of intestine and pharynx, towards the lateral curves of the former with great regularity, and the food contents are throughout the first half of the length of each intestinal ramus in a state of constant agitation. The intestinal rami do not descend into the appendix—at least not in the specimen figured: in other specimens, however, the opposite appeared to be the case. The

appendix is, at the greatest, about one-third of the entire length of the animal. It is very retractile and easily ruptured by undue pressure.

The characteristic serrations on the margins of the body, due to plications of the skin, were not clearly seen.

The main excretory channels are two ducts which curve round from the anterior part of the body and meet behind the ventral sucker, then pass down the mid line of the body to the termination of the appendix as a single channel.

The ovary is situated about half-way between the extremities, ventrally and a little to one side, and is nearly spherical in shape. Immediately posterior to it are the vitellaria. There are two principal lobulated masses. In the specimen figured there are three lobes on one side and four on the other. At the anterior extremities the two vitelline masses are connected together by a short bridge of tissue and from this a short duct connects with the ovary. The shape of the vitellaria is far from being constant, and little value can be placed on the extent to which each lateral mass is lobulated. In some specimens the sub-division was very much less than in the figure.

Over the middle part of the vitellaria was a rounded structure which is apparently the receptaculum seminis. Neither in preparations of the entire worm nor in section, however, could the exact relations of this structure with the vitellaria and oviduct be made out.

The uterus in some specimens is very voluminous. In no case did it descend into the appendix. It is aggregated on the side of the body opposite to the ovary and vitellaria. The ova are very uniform in shape, and the diameters (0·025 × 0·013 mm.) agree very well with

the figures given by Linton for the distomid identified by him as Molin's *D. ocreatum*.

The testes are small, rounded bodies situated one on each side of the ventral sucker, and fairly remote from the ovary. The vasa efferentia curve round to one side of the ventral sucker, and enter the bursa of the cirrus, which lies entirely in front of the sucker, but almost in contact with the latter. The uterus opens externally very near to the male genital aperture, and apparently into a common genital cloaca. Round the extremity of the bursa and the cirrus is a prostate gland, which, however, is not a very prominent structure. The armature of the cirrus itself could not satisfactorily be made out.

The above characters are mostly those of *Distomum ocreatum*, Molin, and I think these specimens may safely be referred to this species.

**Distomum appendiculatum**, Rudolphi.

From stomach of whiting (*Gadus merlangus*), Shoals, March, 1906.

One specimen of an appendiculate distome was found in the stomach of a whiting, along with some other specimens of a distomid not yet identified. The species is probably *D. appendiculatum*, but the diagnostic characters of the distomids with a retractile appendix are rather confused, and it may be worth while to give a description of the present form. The measurements are:—

Length: 5 mm.
Width: 1 mm.
Diameter of oral sucker: 0·17 mm.
Diameter of ventral sucker: 0·4 mm.
Ova: 0·02 × 0·01 mm.

Fig. 14 represents the animal with the appendix

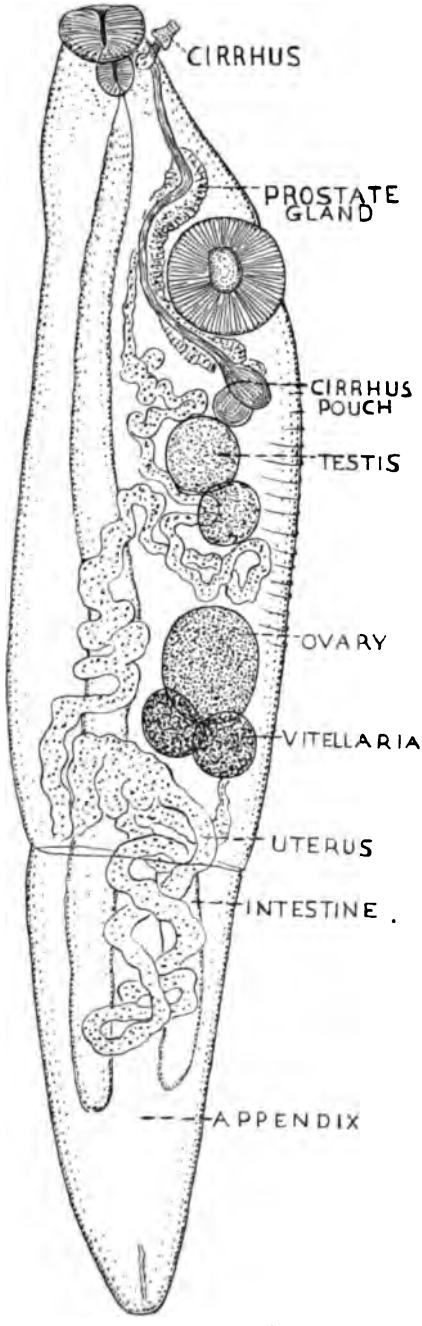



**Fig. 14.** *Distomum appendiculatum.* × 34 dia.

fully expanded. The skin is almost everywhere smooth, and only in one place shows the characteristic plications. The ventral sucker is rather more than twice the diameter of the oral one, and is situated well forward. There is a short pharynx followed by a very short oesophagus. The forks of the intestine are straight and cylindrical, and extend well down into the appendix. The ovary is situated about halfway between the extremities and is oval in shape. Immediately behind it are the vitellaria, which are two in number, small and nearly globular in shape, and in close contact with the ovary. The testes lie midway between ovary and ventral sucker. They are almost globular in shape and lie obliquely across the body. Almost in contact with the anterior margin of the testis are the seminal vesicle and cirrus pouch. The cirrus itself is long, and is surrounded for the greater part of its length with a compact prostate gland. It opens on the posterior margin of the oral sucker. Apparently the female genital aperture is very near to the male opening, but it was not visible in the preparation. The uterus is long and greatly convoluted in the region of the ovary and vitellaria. Like the intestine, it extends well down into the appendix. The worm when alive was translucent, but possessed no distinct colour.

**Distomum vitellosum,** Linton.*

From Flounders (*Pleuronectes flesus*), Piel tanks.

In June, 1906, Mr. A. Scott dissected several mature flounders which had been kept in the tanks at Piel Hatchery during the whole of the previous winter, and found a great number of mature distomids in the

* Linton : Bull. U. S. Fish. Comm., Vol. 10., 1899, p. 290, pl. 37, fig 38.

intestines of several specimens. The characters of these worms agree closely with those of *D. vitellosum*, a species

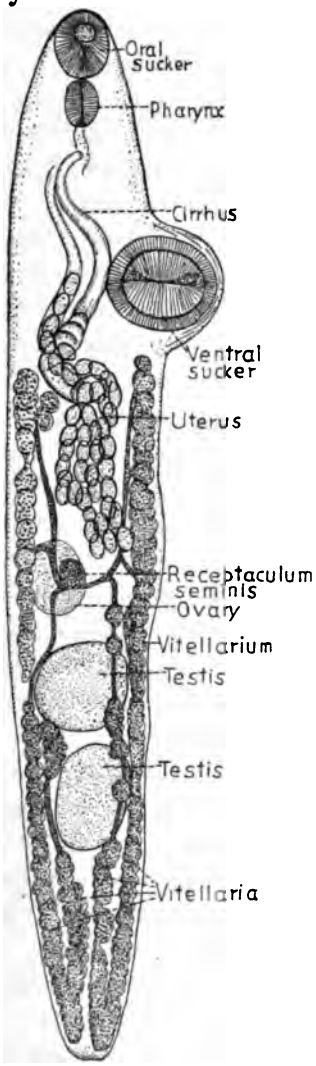



FIG. 15. *Distomum vitellosum*. × 70 dia.

described by Linton from the American hake (*Merluccius*

*bilinearis*), and I think it probable that the distome described here is the above species.

Measurements made from a specimen killed in fresh water and preserved in formalin are:—

Length: 2 to 2·5 mm.
Breadth: 0·25 to 0·5 mm.
Diameter of oral sucker: 0·23 mm.
Diameter of ventral sucker: 0·42 mm.
Diameters of ova: 0·08 × 0·04 mm.

Fig. 15 represents one of these worms seen rather from the side, but slightly twisted. The skin is smooth and without armature; the body sub-cylindrical, and in death with a very noticeable bend towards the anterior extremity. The ventral sucker is very prominent, and is situated on a kind of protuberance. It is nearly twice the diameter of the oral sucker. The pharynx is large, and there is a short oesophagus—the intestinal forks run straight back to near the posterior extremity. The ovary is situated about halfway between the extremities, is globular in shape and rather small. Immediately in front of it is the uterus, which in most specimens formed a compact mass consisting of, apparently, few convolutions and containing a comparatively small number of eggs. The vitellaria are very conspicuous structures, and in many specimens filled the body, almost preventing a proper view of the other genital organs. There are usually four bands of rounded, irregularly-shaped gland; in the figure these bands are seen from the edges, but when the worm is rotated through 90° they appear to be much more voluminous, the bands then being seen from the flat sides. In many specimens the vitelline ducts are very conspicuous, they run through the middle of the band-like masses of vitellaria, and join to form a transverse duct which runs across the body. The ovary is

situated on the course of this transverse duct, and near to it is a small rounded body, which is probably the receptaculum seminis. The ovary itself is a globular structure. The testes are two in number, and are situated at about the posterior third of the body. The cirrus pouch and seminal vesicle lie behind the ventral sucker, and the cirrus runs forward to open near the posterior margin of the pharynx, about halfway between the ventral and the oral suckers. The female genital aperture is situated close to that of the male organs.

**Distomum mollissimum,** Levinsen.*

From intestine of *Belone vulgaris*, Foulney Island, 1906.

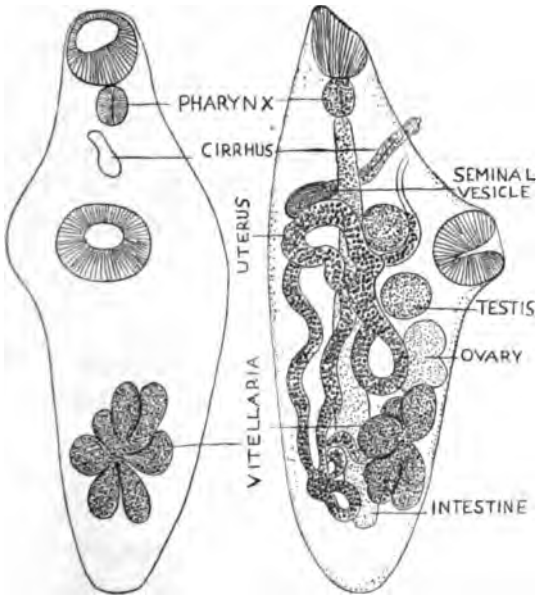



FIG. 16. *Distomum mollisimum.* × 50 dia.

* Oversigt d. k. Danske vidensk. Selskab Forh. No. 1, Tab. 1, 4. Kjobenhavn, 1881.

Several small distomids were sent me by Mr. A Scott, who found them when dissecting a garfish—they certainly belong to the above species. The worm is easily recognised by the star-shaped vitelline glands. It is about 1·5 mm. in length, almost colourless and extremely fragile. Even the pressure of the cover glass is sometimes enough to rupture the preserved specimen. The figure (fig. 16) is constructed from a specimen preserved in formalin. Levinsen found his specimens in the intestine of *Cottus scorpio*. Hitherto all *Cotti* dissected from the Irish Sea have failed to provide this distome.

**Distomum**, sp.

From *Labrus mixtus*, Morecambe Bay, 1906.

Three small distomids from the intestine of a wrasse do not appear to answer to any published descriptions I have seen. The specimens were, however, only seen after preservation in formalin, and it frequently happens that the details of structure necessary for certain diagnosis can only be made out in living distomids. Fig. 17 represents all that can be seen by staining the specimens to which I refer. The measurements of the worm are:—

Length: 1·2 mm.
Breadth: 0·5 mm.
Diameter of oral sucker: 0·11 mm.
Diameter of ventral sucker: 0·24 mm.
Diameters of ova: 70$\mu$ × 50 $\mu$.

The ventral sucker is thus about twice the diameter of the oral one. No details of the oesophagus or intestine could be made out. The vitellaria are represented by a comparatively small number of rather large, irregularly-shaped glands distributed throughout the body. No trace of ovary could be made out with certainty, so it is not represented in the figure. The testes are two large oval

bodies, placed well back near the posterior extremity. Neither the ducts of these bodies nor those of the vitellaria were seen. The cirrus is long, and apparently unarmed. The cirrus pouch and seminal vesicle appear to lie entirely in front of the ventral sucker, but it was difficult to be sure of this. A characteristic feature of the

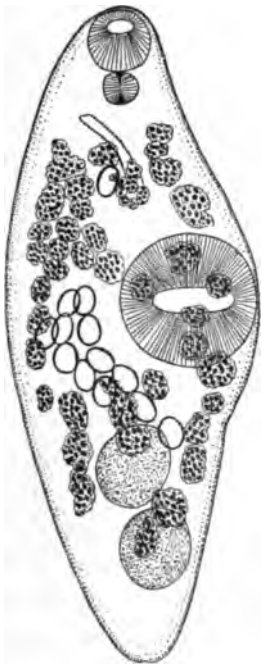


FIG. 17. *Distomum*, sp. × 70 dia.

anatomy of this distomid is the small number of ova. In the three specimens, 12, 13 and about 24 were the numbers of eggs counted. These are comparatively large, are thin shelled and possess no appendages.

In the characters of the vitellaria, the position of the testes and cirrhus and the large size and limited

number of the ova, the specimens agree with *Distomum oculatum* of Levinsen.* But the so-called eye spots of the latter species are not represented in my specimens, and the size of the ventral sucker and the presence of a distinct armature in Levinsen's species render it unlikely that the specimens here described are *D. oculatum*. Several specimens from *Bairdiella chrysura* described by Linton† shew a greater resemblance, but these distomids, too, do not appear to have been identified with any known species.

**Derogenes varicus,** (O. F. Müller).

From pyloric part of stomach of Whiting (*Gadus merlangus*) "shoals," off Cumberland coast, April, 1906.

About half-a-dozen small trematodes were obtained from the above host. The worms were dull red in colour when alive. The figure (fig. 18) is constructed from observations made on the living worm.

The principal dimensions are:—

Total length: 2 to 2·5 mm.;
Greatest breadth: 0·56 mm.;
Diameter of oral sucker: 0·2 to 0·27 mm.;
Diameter of ventral sucker: 0·4 to 0·43 mm.;
Diameters of ova: 0·055 × 0·03 mm.

The body is cylindrical, or very slightly flattened. The greatest breadth is in the region of the ventral sucker, where it is about one-fourth of the total length. From this region the body tapers in both directions and the posterior end is usually slightly more pointed than anteriorly. The skin is quite smooth and possesses no spines.

The ventral sucker is rather variable in diameter,

* Loc. cit.

† Bull. Bureau of Fisheries, Washington, vol. 24, 1904, pl. 23, figs. 168, 169.

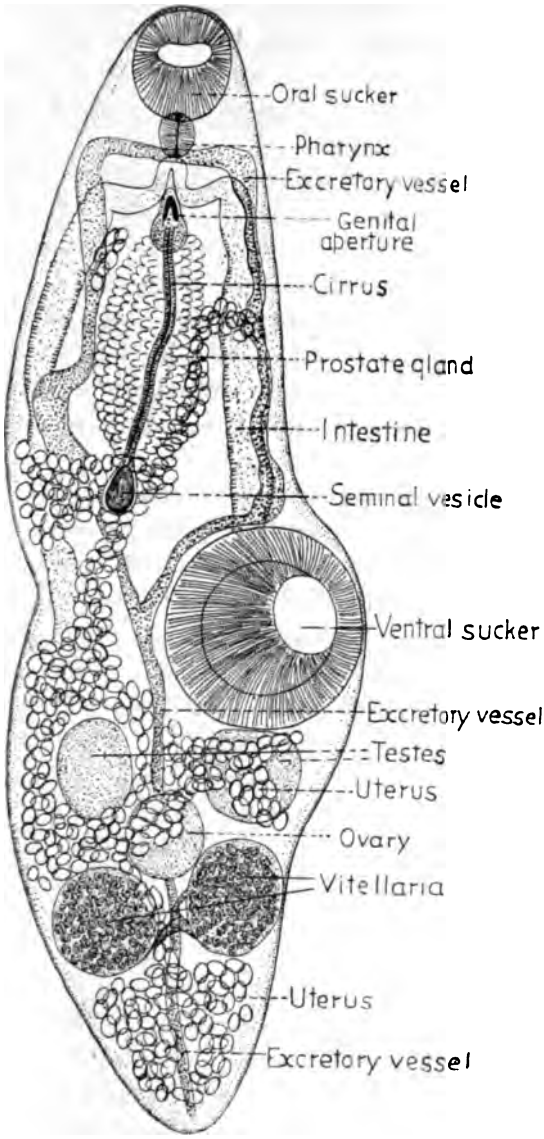



FIG. 18. *Derogenes varicus*. × 75 dia.

but is generally very nearly twice the size of the oral sucker. It is situated rather behind the middle of the body, and in the dead worm, usually on an elevated part of the latter. The openings of both suckers are very nearly circular in outline.

The pharynx is small and oval in shape. There is no distinct oesophagus and no real undivided section of the intestine. From the pharynx the intestinal rami pass transversely to the margins of the body, and then run back as wide voluminous vessels to near the posterior extremity. In the worms, after killing in fresh water, and subsequent preservation in formalin, the walls of the intestine, when seen in optical section, have crenulated outlines.

In the living worms the excretory system is very obvious, but disappears entirely after preservation, and is only indistinctly seen on staining with carmine. The main vessel runs transversely across the body just behind the pharynx, then backwards as two very prominent, rather wide vessels forming a loop. These unite at about the mid transverse line of the ventral sucker, and then pass back in the median line of the body to the posterior extremity. The excretory pore is situated terminally. Often at the summit of a small papilla.

The vitellaria lie far back, about halfway between the posterior margin of the ventral sucker and the posterior extremity of the body. They are rather large bodies, quite regular in outline, spherical, or slightly flattened dorso-ventrally, sometimes oval and elongated in the longitudinal axis of the body. They are made up of a great number of small glandules, but the whole structure is enclosed in a distinct capsule, a short transverse duct unites them and from this the vitelline duct passes forwards to the ovary. The latter is a rounded

structure lying between, and anterior to the vitellaria, and smaller than either of the latter glands. In none of the specimens could I make out with certainty the position and relations of a receptaculum seminis.

The testes are two in number. They are rather small, and not at all conspicuous in either living or preserved specimens. The vasa deferentia cannot easily be traced; probably they are separate and unite quite close to the seminal vesicle, or possibly enter the latter independently. The cirrus and its accessory structures lie all in front of the ventral sucker. The seminal vesicle is small and oval in shape. From it the ductus ejaculatorius passes straight forwards in the median line as an apparently strongly muscular organ, terminating in a prominent genital papilla which is situated immediately behind the forking of the intestine. Throughout all its length, between the seminal vesicle and the genital papilla, the ductus ejaculatorius is surrounded by a very voluminous prostate gland.

In none of my specimens could the exact configurations of the convolutions of the uterus be made out with certainty. It is voluminous in most specimens and is crowded with ova. These latter are thick-shelled and slightly yellow or red in colour. The vagina and cirrus both open into a common genital cloaca, situated at the summit of the genital papilla. The opening of this genital cloaca is in all my specimens Λ-shaped, or crescentic, the apex of the V, or the convexity of the crescent being directed forwards.

Most of these characters would apply equally well to *Derogenes minor*, Looss,* or to *D. varicus* (O. F. Müller).† It is indeed rather difficult to make out absolutely diagnostic differences between these two species. *D. minor* was described by Looss from a

Labroid fish (*Labrus merula*) taken in the Bay of Trieste, and *D. varicus* has various hosts, the latest description being that of Odhner, who found the Trematode in a dab (*Pleuronectes limanda*) from the West Coast of Sweden. Odhner's specimens resemble those described here in that the vitellaria are rounded and regular in outline instead of being slightly mulberry-shaped as in Looss's species. This is the only significant difference apparent between the two species.

## III.—PROTOZOA.

**Ichthyophthirius multifiliis,** Fouquet.

**Trichodina,** sp.

In June, 1906, Inspector Halsall of the Southport Sanitary Department sent some roach which had been living in Hesketh Lake, Southport. Some little time previously an epidemic had broken out among the fishes in this pond. Only the roach were affected, and pike, perch and eels living in the same water showed no signs of disease. The epidemic produced considerable mortality among the roach for about a month, but by the end of July it had run its course, and there were then thousands of young fishes in the lake, all of which appeared to be quite healthy. The fish, when received at the laboratory showed no apparent outward signs of illness. The skin was bright and clean and without traces of fungus. Dissection showed no internal lesions, and smears made from the blood and various organs

* Looss: b. Einige Distomen der Labriden des Triester Hafens, Centralbl. f. Bakteriologie, Bd. 29, Abth. 1, p. 487, 1901.

† Odhner: Die Trematoden des Arktischen Gebietes; Inaugural Dissertation; Univ. Upsala; Jena, 1905.

shewed that parasites such as myxosporidia were absent. The gills were then examined, and these were found to be pale and not in a very healthy condition; also small, rounded white specks could just be seen with the naked eye, and when these were examined in detail they were seen to be ciliated infusorians. Fig. 4, pl. VIII, represents one of these organisms. They varied greatly in size, the largest being about 0·75 mm. in length and 0·47 in breadth, and the smallest about 0·3 × 0·28 mm. Usually they were oval in shape, but some were quite round. Their numbers were not considerable; in a small piece of gill, from one of the smaller fishes, which was stained and mounted whole there were 17 parasites. There were 30 double filaments in this piece of gill. In some other pieces of gill roughly examined the parasites appeared, however, to be more abundant than is stated above. They lie in the gill between the filaments and compressed by the latter. They were also found on the internal walls of the operculum and branchial cavity. The parasite is completely covered by fine cilia. The nucleus is situated towards one end, or near the middle of the body, and is large and horse-shoe shaped. It is very coarsely granular. The mouth is situated at the opposite end and is small and very definite in outline. A faint, longitudinal striation may be observed in the body. Round the margin, or rather underneath the cilia, is an evident cortical layer. Small vacuoles are very numerous in some specimens.

All these characters are those of *Ichthyophthirius multifiliis*, Fouquet, and I have no hesitation in thus identifying the creature. It is a skin parasite, which has been described as infesting 28 or 30 species of fresh-water fishes in the rivers and lakes of Germany, France, Holland and the United States of North

America.* So far as I know, it has not previously been observed in British waters. The parasite is always described as inhabiting the skin of the infested fish, where it excavates little cavities or galleries or forms pustules. These cavities or pustules may contain one or a number of individual parasites. A characteristic spotted appearance is thus conferred on the skin of the fish. *Ichthyophthirius* reproduces either by fission (Stiles), or by the method of encystment. Eventually the parasite leaves the host, and after swimming about in the water for some time surrounds itself by a cyst wall, when it falls to the bottom. The young ciliated individuals leaving the cyst then pass through a free-swimming stage and reinfect fresh hosts. It is by attacking these free-swimming forms that the epidemic in a tank or small pond can most easily be fought. It appears to be impossible to destroy the parasites while living in the skin of the hosts, but if the fishes be taken from the aquarium and common salt added to the latter with a copious supply of fresh water the free-swimming individuals are easily killed. This treatment, practicable though it may be on a small scale, is, however, difficult in the case of a very large pond or "lake."

It is difficult to say what the specific pathogenic action of the parasite may be. In the roach from Hesketh Lake there was no general infection of the skin—indeed I could not detect the parasite there in any of the specimens examined. Even in the gills the numbers were few, and it seemed difficult to believe that the mechanical destruction of the tissues of the filaments was enough to account for the death of the fish. It was, however,

* There is an account of the parasite, with a summary of the literature by C. W. Stiles in Bull. U.S. Fish. Comm., vol. 13, 1893, pp. 173-190. See also Hofer, Handbuch der Fischkrankheiten, p. 122; Munchen, 1904.

impossible to avoid associating the presence of the infusorian with the death of the fish, as no other cause was apparent which would account for the large mortality experienced. It is just possible that the infusorian kills the fish by forming a toxine which is absorbed through the delicate epithelium of the gills, or at the abraded surface of parts of the latter structures.

Associated with the *Ichthyophthirii* in some of the fishes were infusiorians belonging apparently to the genus *Trichodina*. This is the well-known ciliate found on the common *Hydra*. The number of specimens found were, however, few, and in such bad condition that the certain determination of the species was not possible.

**Lymphocystis johnstonei,** Woodcock.

A small sole was sent to the Laboratory in April last by Dr. Masterman, H.M. Inspector at the Board of Agriculture and Fisheries. The fish was captured off the East coast of England by a steam trawler, and sent to the officials of the Board in a sample box of various fishes. The fish is an immature female about $7\frac{1}{2}$ inches in total length, and was apparently healthy and in good condition. But the greater part of the surface of the skin was covered over by very small, white, and spherical opaque bodies which were evidently parasites of some kind. They were densely scattered over the ocular side of the fish particularly on the dorsal and ventral regions of the body. On either side of the lateral line the skin was very nearly free from them, but, towards the dorsal and anal fins they became more densely aggregated together. On the fins they were most abundant, particularly on the dorsal fin near the head and on the tip of the pectoral fin. Here they formed dense clusters seated on most of the fin-rays. The skin of the head was

densely covered with these structures; the tail also contained a few; the blind side of the fish also showed a certain number, but far less than on the ocular surface—probably on account of the attrition caused by the fish creeping over the surface of the sand. The little bodies in question were quite colourless, but very opaque, and easily discernible by the naked eye. They were nearly spherical in shape; flattened perhaps in one direction, and where they were closely packed together—as in the clusters on the fins—their shapes were polygonal. Their average diameter was about 0·32 mm.

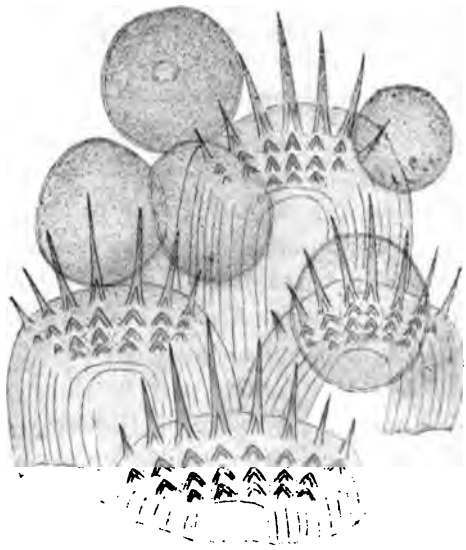


FIG. 19. Skin of Sole infested with *Lymphocystis johnstonei*. × 60 dia.

The fish had been preserved in formalin and the skin and the structures on and in connection with it were well preserved, but the body cavity had not been opened and the viscera were not in good condition for close examination. But, apparently, the peritoneum and mesenteries

were quite free from the parasites occurring on the skin. The gills were also free and apparently quite healthy.

Fig. 19 represents a general view of a part of the skin which has been stained with carmine and cleared in clove oil. The parasitic structures are mostly covered by the scales. Each is covered over by a thin fold of epidermis. Usually they are situated beneath the posterior margin of the scales under the fold of epidermis which is reflected over the latter. Sometimes they are apparently quite free from the surface of the skin and can easily be detached by the point of a scalpel, but in such cases they are attached by a delicate pedicel of epidermic tissue. In sections of the skin taken in a transverse plane they can be seen lying beneath the tips of the spines of the scales, which are then cut transversely.

In section each of the parasitic bodies is almost certainly a unicellular structure. It is surrounded by a fairly thick, apparently structureless capsule, which stains with difficulty and is, therefore, more easily seen in the unstained preparations. Within is the cell body, containing near the centre an irregularly-shaped included portion surrounded by a differentiated portion of the matrix, which may represent a nuclear membrane. Within this is what may be called a nucleus. There is a matrix of finely granular substance in which are usually two or more rounded karyosomes.

The cell substance outside the nucleus stains rather more darkly than that within because of the presence of numerous granules. It shows no clearly marked cortical zone, but round the periphery are a number of reticular structures, very irregular in shape and size, and usually surrounding a portion of cell substance which stains more lightly than that in which the reticula are imbedded. Each of these reticula appears to consist of innumerable

closely apposed granules, which take chromatic stains very easily. Close underneath the capsule, again, are a number of smaller, more closely aggregated collections of similar granules, usually spherical, or nearly so, in shape, and staining less deeply than the reticula just described.

Most of the structures above described are to be seen in the remarkable sporozoan, *Lymphocystis johnstonei*, described by Woodcock,* and it is difficult not to identify the two parasitic structures as the same organism. The mode of occurrence of the structures—on the skin and fins—is the same, and despite the difference in size I regard it as probable that in the case just described we have to deal with an invasion of *Lymphocystis* individuals, and that the nature of the host and, particularly perhaps, the nature of the skin of the sole—where we find strongly ctenoid scales, instead of the comparatively soft cycloid structures found in the flounder—is the reason of the difference in size. The difference in diameter, 0·32 mm. and 1 to 1·5 mm. in the sole and flounder respectively, may easily be explained by such considerations, and one may, indeed, find many examples of analogous differences in size in identical parasitic species living on somewhat different hosts.

## IV.—DERMAL CATARRH IN SALMON AND DAB.

Two cases of pathological changes in the skin of fishes have been observed which do not appear to be referable to parasitic invasions of any kind. In September, 1904, Mr. R. Okell sent me some salmon parr caught in a stream near Douglas which appeared to be suffering from some obscure skin disease, obviously not due to *Saprolegnia*. Fish thus infected were quite

* In An. Rept. Lancashire Sea Fish. Laby. for 1903, pp. 63-72, pl. III.

abundant at this time, but about the middle of October the epidemic had greatly subsided, though even then about 10 per cent. of the salmon parr observed seem to be infected. The extent of skin affected in the case of specimens caught at this time also appeared to be less than formerly was the case. All this time salmon parr alone were infected. Brook trout do not appear to have suffered.

Fig. 5 (pl. VIII) represents the tail portion of one of these fish with a characteristic skin lesion. In all cases the naked eye appearance was pretty much the same as that figured, though not always so prominent. In the less strongly infected fishes the skin appears to be covered in places with a thin, whitish scum, like felted or compressed cotton wool. This can easily be rubbed away and then the skin underneath appears to be quite normal, the scales retaining their usual appearance. Here and there this growth is, however, much more prominent. For instance, in the case figured there was a raised whitish tumour on each side of the body just above the anal fin. This growth was raised about 2 mm. above the surface of the skin. It had usually a slightly crenulated margin and had surface markings indicating roughly the position of the scales underneath. In the case of some of these larger growths, however, the skin underneath the adventitious tissue was disorganised and the scales came away easily.

Microscopic examination showed no traces of a mycelium so the presence of a fungus was out of the question. Neither were there any traces of Myxosporidia. These were specially looked for as the naked eye appearance of some of the fish was not unlike the condition of "Beulenkrankheit" (Myxoboliasis). Smears were made from the blood and from all the visceral organs,

and portions of muscle tissue were examined, but no trace of myxosporidia could be detected. The gills, too, were quite normal. The skin growth was examined further for the presence of Infusoria, such as *Costia*. *Costia necatrix* produces appearances on the skin of various fishes not unlike that observed in this case. In fact, it was possible to eliminate the possibility that sporozoan or infusorian parasites were responsible for the condition. The possibility that bacteria were concerned was also considered, but a search for these was unsuccessful, and I had no opportunity of examining fresh material.

Sections of the skin, including portions of the growth were then made and stained with methyl-blue-eosin, and Heidenhain's iron haematoxylin.

Part of such a section is represented in fig. 1, pl. VIII. It will be seen that the skin is very much altered. The scales are in some cases quite displaced, and may even be seen buried up in the tissue of the tumour. The dermis is always quite unaffected; whatever the disease is it affects only the epidermis. This latter layer is quite changed. In a normal fish it consists of roughly polyhedral cells lying close together, and contains large mucus cells included among the others. At the base is a very regular layer of cubical cells, and at the free surface of the skin the epidermal cells become flat and horny. The tissue of the tumour replaces the epidermis, which, as a normal structure, has entirely disappeared. Instead of it we see a densely compacted mass of smaller cells. These are arranged in aggregates somewhat resembling tubercles. In the axis of each tubercle is a core of fibrous tissue, with a structure very difficult to determine; and here and there cavities containing groups of small bodies, not unlike, in size and shape, masses of

myxosporidian spores. A small portion of the tumour as seen with a high power immersion lens is depicted in fig. 2, pl. VIII. Part of the core of one of the tubercles is shown with a number of the small oval bodies referred to. These have an average length of about 5$\mu$. They stain densely with eosin or iron haematoxylin, and show no obvious structure. They are not at all numerous.

The rest of the tissue consists of cells of various sizes, with apparently some structureless material serving as a matrix. There are two kinds of these cells. One kind stain densely, are rather smaller than the others, and show a definite nucleus The other kind appear also to be nucleated, though it is difficult to be certain, and are larger. Indeed one can easily say too much regarding the cytology of this tissue, for the preservative was only formalin and I had no opportunity of fixing the thing properly.

I think the only probable explanation of this condition is that it represents a catarrh of the skin, such a condition as is described by Hofer* as "Erkaltungskrankheiten." I have not seen any such condition as is represented by Hofer's plates VIII and IX, but the general "turbidity" of the skin, the delicate waxy bloom which he speaks of, is well shown in some of these specimens. It appears to be a paradox, Hofer says, to speak of a fish as catching cold or catarrh; still that such an ailment should be experienced by a fish is not so surprising as it at first appears to be. In a cold blooded animal the heat regulating mechanism, which is so characteristic and important a feature in the physiological economy of a warm blooded creature, is conspicuously absent. The temperature of a fish is always that of the medium in which it lives, or only a very little higher.

* Handbuch der Fischkrankheiten. München. 1904. p. 87.

Such sudden changes of temperature as a warm blooded animal must accustom itself to are as a rule not experienced by fishes, for changes in the temperature of even a small mass of water such as a pond take place much less rapidly than corresponding changes in the atmosphere. Nevertheless, there are circumstances in which the water temperature may change fairly rapidly --such as, for instance, would be produced by the quick migration of a fish from one part of a small stream into another, or into a pond; or, perhaps, by a sudden freshet in a small stream produced by cold rain or melting snow. Still more would such change be experienced by fishes living in captivity as for instance in fish-breeding establishments; and it is chiefly in relation to fishes living in these conditions that catarrh of the skin has been observed and studied.

These Manx salmon parr were then probably suffering from some kind of dermal catarrh. Indeed I can suggest no other explanation of the lesions observed.

The other apparent cases of dermal catarrh observed were in several dabs (*Pleuronectes limanda*) which have been taken during the last year or two. One fish brought to the Piel fishermen's classes in April, 1906, by Capt. Wignall showed the condition very well. The fish was a mature male with ripe testes and apparently in normal condition. But on either side near the tail was a soft, white, slightly translucent tumour not unlike those described from the Manx salmon parr. The tumour had a papillated surface, was about 1 cm. in diameter, and about 2 mm. in height. In the fresh condition there was an irregular radiate arrangement of blood capillaries infiltrating its mass. Smears from a part of this growth were made and stained by Romanowsky's method, and also by Heidenhain's iron haematoxylin. The blood of

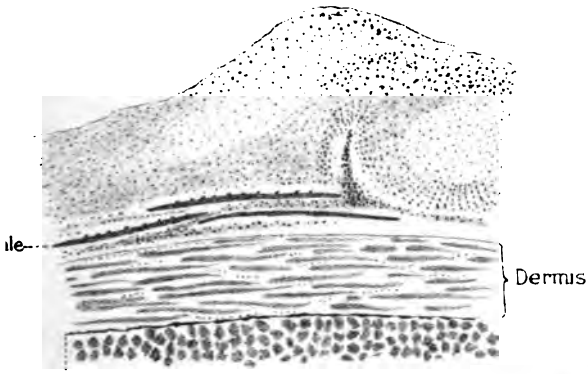



FIG.1.

FIG.3.

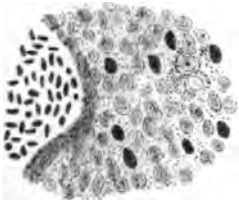


FIG.2.

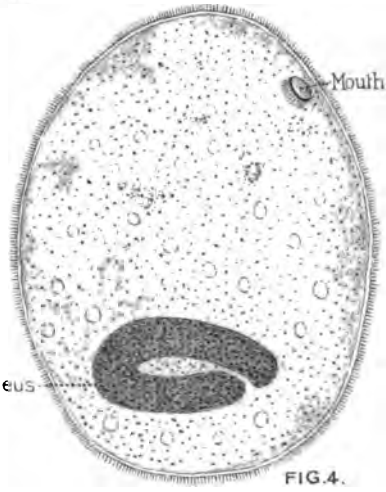



FIG.4.

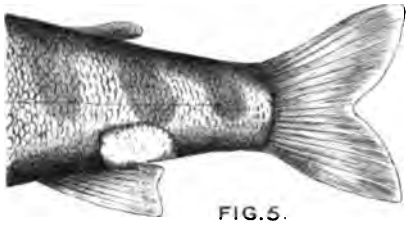


FIG.5.

1-3. Tumour on skin of Salmon Parr.

4. Ichthyophthirius multifiliis Fouquet

5. Tail of Salmon Parr with tumour.

J. Johnstone, del. S.B. lith

the fish was also examined, but was quite normal. Indeed, with the exception of the tumour described no other evidence of disease could be discovered.

The tissue of the tumour showed a general resemblance to that described in the case of the young salmon. But there was a much larger quantity of broken down material, of a finely granular nature, lying between the cells. The latter are apparently epidermal cells altered considerably, staining only very lightly with Romanowsky, but deeply with iron-alum haematoxylin. Among these cells are nests of bacteria staining well with Romanowsky. Several of these are represented in fig. 3, pl. VIII, and it will be seen that they are of very various forms. The long delicate bacillus occurs rather rarely; it is about 10 $\mu$ in length. Other forms are short curved rods and thick, dumpy bacilli, most of which stain as if spore formation were in progress, but are probably only the involution forms of a bacillus akin to the long slender forms. These bacilli are not very numerous, though a fair number could be seen in every field. An attempt was made from the fresh tissue to set up a cultivation on nutrient gelatine at ordinary room temperature, but no results were obtained. Probably they represent only a secondary infection on a partially broken down proliferation of the epidermis. The whole appearance of the latter is so similar to that in the Manx salmon parr that I am inclined to regard this also as a case of dermal catarrh. A mechanical injury is out of the question as the skin underneath was almost normal and no traces of infection by a sporozoan or other parasite could be detected.

# ON A MYXOSPORIDIAN INFECTION OF *GADUS ESMARKII*.

By Jas. Johnstone.

## WITH A NOTE ON THE IDENTIFICATION OF THE PARASITE.

By H. M. Woodcock, D.Sc., Lister Institute of Preventive Medicine.

## I.

In 1889 Günther* first recorded the presence of the Norway Pout, *Gadus esmarkii*, in British waters. This fish, previously known only in Scandinavian waters, was noted by Gunther in the Firth of Clyde, and in some of the Western Scottish Lochs, at depths varying from 26 to 80 fathoms. Speaking of the characters of the fish Günther says, "Many of them suffered from a singular affection of the eye, namely the whole eyeball, and also a greater or lesser part of the iris, being covered with cysts containing a cheesy matter."

Again in 1900 Fulton† makes a similar observation. *Gadus esmarkii*, belonging to the so-called Scottish and Scandinavian types, was found by him in the Northern part of the North Sea, where it appears to be fairly abundant, and in the Firth of Clyde. Fulton says that "a very large proportion of those taken in the Firth of Clyde had one or both eyeballs affected in the manner described by the author named [Günther], (the cysts, however, containing fine granules) but no specimen from the North Sea was observed to be so affected."

In March of 1906, a Norway Pout was caught in a

* Proc. Roy. Soc. Edinburgh, vol. 15, 1889, p. 212.

† Rept. Scottish Fishery Board, 19, pt. 3, 1900, pp. 282-4.

shrimp-trawl worked in shallow water near Morecambe, and sent to me. This specimen had both eyes affected in the manner described by Günther and Fulton.

These are the only instances of this affection of the eye which, so far as I am aware, have been observed. Although the fish has been known for a long time on the coasts of Scandinavia, and has since been found on most of the coasts of the British Isles, the eye parasites have only been found on the West Coast of Britain. Probably the specimen found at Morecambe is one of many which have migrated into the Irish sea through the North Channel.

Fig. 1, pl. IX represents the head of the specimen (twice natural size). The eye is perhaps larger than in normal specimens. Round the peripheral part of the cornea, and covered losely by conjunctiva are a number of milk-white rounded or oval bodies, from about 1 to 3 mm. in diameter. Several of these have fused to form elongated masses, which take the curvature of the periphery of the eye. Growing out from the lower margins of this ring is a botryoidal mass of similar material which encroaches on the pupil. When one of the eyes was removed it was seen that these adventitious structures had invaded the lateral and posterior parts of the bulbus oculi.

These structures remind one of pustules. When pricked (in the fresh condition) a thick, white, pus-like substance could be squeezed out. But when a trace of this was examined under even a low power of the microscope it was immediately seen that the structure was a Myxosporidian cyst. The "fine granules" filling up the interior were spores containing two polar capsules, and in some cases, two polar filaments were seen under a high power.

Fig. 8, pl. IX represents a nearly meridional section of the wall of the bulbus oculi. Apart from the shape of the bulbus, and the presence of the processus falciformis and campanula, the fish eye does not differ greatly from that of higher Vertebrates. In the wall, however, we find a choroid layer possessing features solely piscine, and also the peculiar argenteal layer. The sclerotic consists of two layers, (1) a layer of cartilage, ceasing some distance behind the iris: on the internal surface of this is the argentea; and (2) a fibrous layer which lies external to the cartilaginous layer. This feature is, of course, paralleled among other Vertebrata.

The intrusive cysts lie within the thickness of the cartilaginous layer of the sclerotic. This latter is, of course, quite thin in the normal eye, whereas in the diseased specimen the cysts are sometimes over 2 mm. in diameter. The multiplication of the Myxosporidian within the cartilaginous sclerotic has, therefore, distended the latter layer. In section a layer of cartilage, sometimes, however, very thin, can be traced all round the cyst. In other parts of the section the cartilage thins out and almost disappears, being either mechanically stretched or, perhaps, reduced by the reaction of the Myxosporidian tissues. The other parts of the eye were apparently quite normal. The function of the organ had not apparently been affected; though it is probable that a kind of cataract might easily be induced by the invasion of the cornea by the cyst masses. This process has indeed begun in the eye figured. J. J.

## II.

Mr. Johnstone kindly sent me a couple of smears made from the contents of one of the cysts above described, expressing his opinion that a Myxosporidian parasite was concerned, and asking me to identify it. On examining the smears, I saw that they consisted entirely of spores, evidently belonging to a Phaenocystan parasite, for two brightly refringent polar capsules were visible in each. One of the slides was stained with Heidenhain's iron-haematoxylin, the other with thionin. For some reason or other the first method did not prove a success, the stain persisting in the spore-wall in a rather blotchy manner, and obscuring the contents; while the polar capsules did not retain it at all. By the second method the spore-wall itself remained unstained, the polar capsules were deeply stained, and the various nuclei, though not retaining the stain as much as was desirable, could often be made out with a little trouble.

Two spores are seen in fig. 2. In shape they are slightly ovoid, their dimensions averaging 10 $\mu$ in length by 8 $\mu$ in breadth. The two polar capsules (*p.c.*) are situated near one end of the longer axis; the length of each varies from $3\frac{1}{4}$ to $3\frac{1}{2}$ $\mu$. Unfortunately, I could not find a single spore in which either or both of the polar capsules had the filament evaginated. This was a little surprising, as in a similarly prepared slide of another parasite (*Sphaerospora platessae*) which I have previously characterised,* the stimulus of spreading the smear had caused many of the capsules to evert their filament. So that I have not been able, so far, to ascertain the length of the filament in the spores under discussion. Occupying a considerable portion of the sporoplasm is a large, well-

* Woodcock, Proc. L'pool Biol. Soc., Vol. XVIII., p. 140 (1904).

defined vacuole (*i.v.*) which is invariably present. This is the iodinophilous vacuole, which is characteristic of all members of the *Phaenocystes* belonging to the family Myxobolidae. The nucleus in connection with each polar capsule—the nucleus, *i.e.*, of the so-called "capsular cell," or portion of the pansporoblast from which each capsule is formed—is shewn at (*n.p.c.*). The two germ-nuclei of the undivided sporoplasm are visible at (*N*). It may be added that, in one or two instances, I could make out a slightly deeper-staining line or thickening just internal to the spore-wall on either side. These probably represented the nuclear remains of those other portions or organellae of the pansporoblast, which, as recently shewn by Léger and Hesse,* give rise to the two valves of the spore. As, however, I did not feel quite sure of them, owing to the faintness of the staining, and as neither of the spores drawn actually shewed them at all, I have not included them in the figure.

With regard to the systematic position of this parasite of *Gadus esmarkii*, the simple shape of the spore, lacking any tail-processes, makes it apparent that it must be included in the genus *Myxobolus*; and, further, the presence of two practically equal polar capsules places it in the corresponding section of this genus. The dimensions of the spore do not agree at all closely with those of any Myxobolan spore, belonging to this section, which has so far been described. Moreover, up till now no Myxosporidian has been known to occur in one of the Gadidae. Hence it is most probable that this *Myxobolus* is a new species, for which I propose the name *M. esmarkii*.

H. M. W.

* Léger and Hesse, C. R. Ac. Sc., 19th March, 1906.

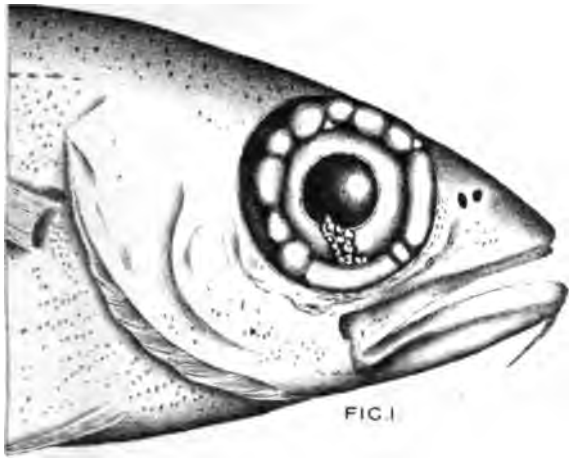


FIG. 1

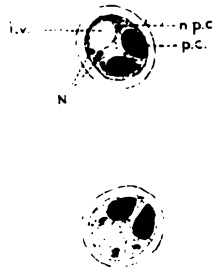



FIG. 2.

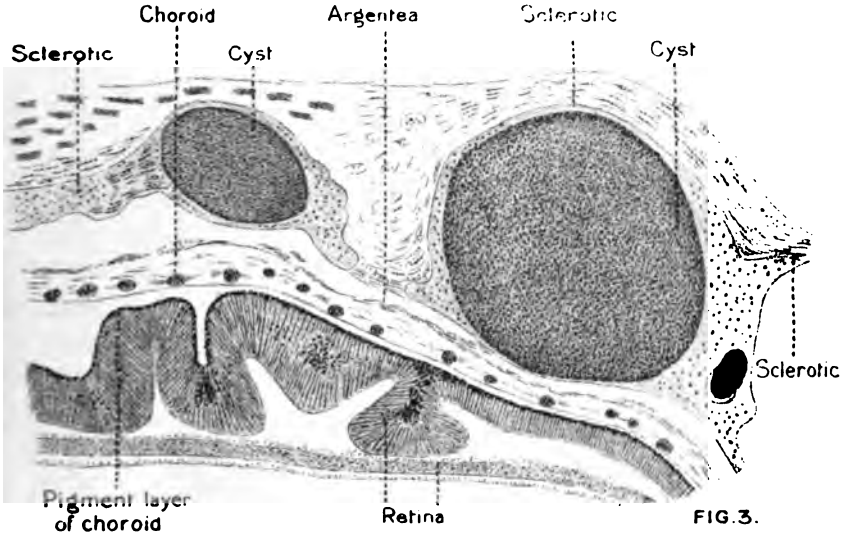



FIG. 3.

## MYXOBOLUS ESMARKII.

1. Head of Gadus esmarkii with infected eye.
2. Spores of M. esmarkii.
3. Section of optic bulb with infected sclerotic

*Figs 1 & 3. J. Johnstone del*
*Fig 2. H.M. Woodcock del.*

S.B. lith.

# ICHTHYOLOGICAL NOTES.

JAS. JOHNSTONE.

## (1) An hermaphrodite hake.

In June last, Mr. W. Wright, a fisherman who had attended the classes at Piel in 1905, recognised that a hake which he was gutting on board a steam trawler, fishing off the West Coast of Ireland, was possessed of hermaphrodite organs. The viscera were, therefore, preserved in some spirituous liquid and handed to Capt. Wignall, who sent the specimen to me. In the course of dissection, which is always a much more rapid process on a steam trawler, than in a laboratory, the viscera had suffered considerably, and the relations of the genital ducts, urocyst, and alimentary canal were not at all clear in the specimen when it reached me. Nevertheless, there is no doubt that the organs are those of a hermaphrodite hake.

Both ovaries are present. That on one side is 5·5 × 3·25 cm. in diameter; that on the other side being 6·5 × 3·5 cms. in the corresponding dimensions. They are apparently normal organs, hard, and crowded with small ova, and not dissimilar in structure and stage of ripeness to the ovaries of a normal hake at the same stage of development and at the same period of the year. The ova are about 0·8 mm. in diameter.

At the posterior end of each ovary is a testis. These organs have the shape and appearance characteristic of a well-developed gadoid testis. They are apparently incomplete so I do not give their dimensions. Both are equally well developed, and each is larger than the ovary to which it is attached. They are convoluted in the usual manner though the convolutions are not so

numerous or complex as in a normal male fish. A thick sheet of peritoneum, loaded apparently with fat, connects the two testes. On cutting open the ovaries there was no perceptible lumen, except at the posterior end, where the substance of ovaries and testes became confluent. At this place the lumen of the ovary was continuous with that of the proximal part of the testis.

Cases of hermaphroditism in most teleosts, especially in Gadoid fishes, are, of course, very rare. Nevertheless, a fair number of hermaphrodites have been described. The earlier literature is discussed, and the instances of hermaphrodite codfish cited in the well-known paper by Howes* on the "Hermaphrodite genitalia of a codfish," a further instance as recorded by Ramsay Smith,† and other cases are recorded by Masterman,‡ who discusses the cases recorded later than those in Howes' classical paper. The specimens figured by Howes and Masterman were apparently functional females. Whether or not ripe spermatozoa were extruded by these fishes while alive is difficult to say, but probably the male organs were functionless. In Ramsay Smith's specimen (from a haddock) the testes and ovaries were equally well developed, but the former were relatively larger than in Howes' specimen, where the testis formed a small rosette-shaped structure at the extremity of the ovary. In Masterman's specimens the testes were small and there were a few ripe eggs in the mouth of the oviducts. These fishes were, therefore, probably functional females. In the specimen now before me we have what is probably a functional male fish. The testes are well developed and there is free communication between them and the

* Journal Linnean Society, vol. 23, 1891.

† Rept. Scottish Fishery Bd., vol. 9, p. 352 1891.

Do. do. vol. 12, plates 3 and 4, and vol. 13, p. 297, 1893.

cavities of the ovaries and oviducts. If ripe spermatozoa were extruded these must have been emitted through the (normal) female genital aperture.

In the southern Irish Sea the hake appears to spawn later in the year than its allies. Holt* found ripe specimens as late as July, and concludes that, in the Irish seas, the spawning period of the hake may be prolonged from March until the end of July. Ewart† found that the spawning took place late in the year, and M'Intosh reports a ripe male in August on the East Coast of Scotland. Apparently, then, the fish may spawn about midsummer, and, if so, the hermaphrodite specimen here described was a functional male—that is if the fish were sexually functional at all—for the ovaries were those of a fish which certainly had not spawned during the year when it was caught, and apparently would not have done so had it remained in the sea. On the other hand the testes had all the appearance of nearly ripe functional organs.

It was interesting to note that two or three small pear-shaped bodies possessing all the structure of a testis, were attached to the outside of one of the ovaries some distance from the place where the main testicular mass and that of the ovaries joined.

**(2) Gurnard (*Trigla gurnardus*) with malformed lower jaw.**

A small grey gurnard sent me some time ago by Captain Wignall shews an interesting malformation of the lower jaw. The head of this fish is represented in fig. 20. Seen from the side a notch appears to have been cut out from the mouth of the fish, and even without dissection the peculiar appearance is seen to be due to

* Sci. Proc. Roy. Soc. Dublin, vol. 7, p. 401, 1892.

† 7th An. Rept. Scottish Fishery Board, pp. 3, 196, 1889.

the absence, or at least great reduction in the size, of the lower jaw. The upper jaw overhangs the mouth which is reduced to a small crescentic slit on the lower side of the head; both jaws are quite immovable. Whatever food the fish obtained must have been of very small size. There were no recognisable food remains in gut or stomach. Nevertheless the fish appears to be healthy and in good condition.

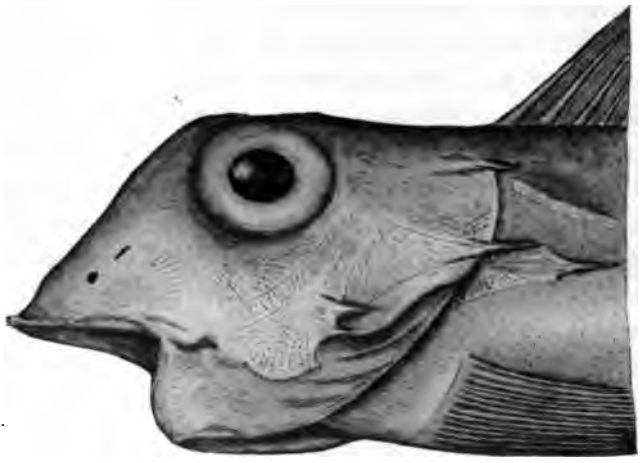


FIG. 20. *Trigla gurnardus*. Natural size.

Fig. 21 represents the normal suspensorium and jaw apparatus of a grey gurnard, and it will be seen that we have here the type which, with no essential variation, is encountered among almost all teleostean fishes. In the abnormal skull now before us (fig. 22), the parts of the suspensorium and upper jaw are essentially as in the normal skeleton. The palato-pterygoid arcade consists of the same bones, and in the same relationships as in the normal skull. So also with the maxilla and pre-maxilla. The palato-pterygoid arcade is, it is true, shifted dorsally

to a position much nearer to the ventral surface of the skull, and this is also the case with the bones of the upper jaw. But otherwise all are quite normal. The difference in the two skulls lies in the lower jaw. In the normal skeleton this consists of the usual parts, dentary, articulare and a very small angulare, and is rather massive. In the abnormal skull these parts are altogether different and are much dwarfed. There is no apparent angulare, but, perhaps this is ossified together with the articulare. This element

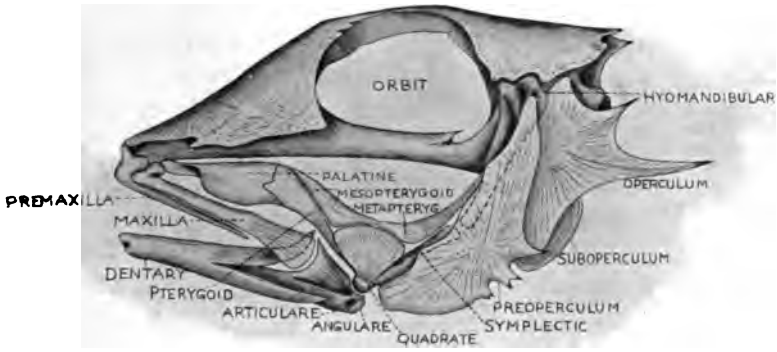



FIG. 21. Skull of *Trigla gurnardus*. Natural size.

is not at all like the normal bone; it is an irregularly shaped bone the long axis of which is dorso-ventral. On its posterior surface is a saddle-shaped articular surface which receives the articular knob of the quadrate. In front and a little above this is a socket-shaped articular surface into which the proximal end of the lower jaw proper fits. The latter consists of an apparently single bone, which is a flat hoop forming the lower margin of the gape. It probably is the fused and completely ossified Meckelian cartilages, whether or not

membrane bones are included in it is not certain, but it probably represents only the two Meckel's cartilages. From these parts, and the articular elements, a strong tendinous and muscular sheet of tissue passes ventrally and is inserted into the hypohyal elements of the hyoid arch. It is the latter which form the prominent "chin" shewn in fig. 20.

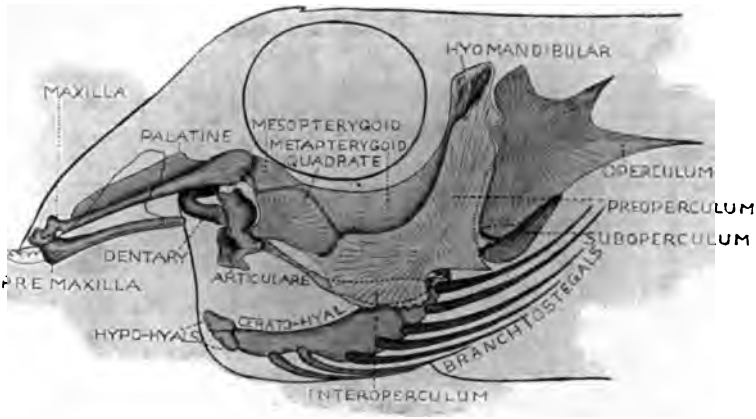



FIG. 22. Malformed skull of *Trigla gurnardus*. Slightly magnified.

Malformations of this kind are extremely rare among teleostean fishes living in nature. Probably individuals exhibiting them are eliminated at an early stage of their life history. If, as is probably the case, the malformation here described was developed during the post larval stage it is difficult to see how the fish contrived to secure enough food. But it is probable that the gape was of greater extent in this stage, and that the very contracted mouth opening was only developed after adult growth had been attained.

**Gadus esmarkii**, Nilsson.

The Norway Pout, although by no means an infrequent fish in British waters, has not until the spring of this year been recognised on the eastern side of the Irish Sea. Probably it is not uncommon among the shoals of small whiting which at times frequent the shrimping grounds. The specimen referred to here was caught by a shrimper near Morecambe, in March, 1906, and was sent to me by Mr. Ed. Gardner. It was a gravid female, containing ripe ova. Both eyes contained a myxosporidian parasite, which is described above.

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NOTE.—While this report was going through the press Mr Ragdale, Chairman of the Scientific Sub-Committee, noticed in the Manchester fish market a fine specimen of *Beryx splendens*, Lowe, measuring twelve inches from extremity of head to root of tail. It was caught off the S.W. coast of Ireland in Lat. 49° 10′ N. Long. 11° W. The specimen has been presented by Mr. W. Vernon to the Manchester Museum.—W. A. H.

# THE FOOD OF FISHES.

By Jas. Johnstone.

Observations on the food of comparatively few fishes have been made. The following lists refer to the examination of the stomachs of 114 plaice and 146 dabs. The observations were made not as part of a systematic scheme for the investigation of the food of fishes in general, but rather with the object of exhibiting the contrast between the food of plaice and dabs caught on the same fishing ground and in the same hauls of the net. I give the numbers of both kinds of fish taken in the hauls; the sizes of the fish are not given, but generally plaice of 9 to 12 inches in length, and dabs of 7 to 10 inches were examined. The contents of the stomach and intestines are given for each fish examined and the observations relating to plaice and dabs caught together are put in parallel columns.

## 1. Plaice and Dabs.

3rd January, 1906.—Blackpool Closed Ground. Catch: 3 plaice, 77 dabs:—

3 plaice and 6 dabs examined, but all had empty stomachs.

9th January, 1906.—Beaumaris Bay. Catch: 146 plaice, 109 dabs:—

| 7 plaice. | 8 dabs. |
|---|---|
| 4—Empty. | 3—Empty. |
| 1—Scrobicularia. | 1—Mactra. |
| 1—Solen and Scrobicularia. | 1—Mactra and Crangon. |
| 1—An amphipod. | 1—Foot of Cardium. |
| | 2—Ophiurids. |

20th February, 1906. —"Shoals." Catch: 23 plaice, 29 dabs:—

| 7 plaice. | 14 dabs. |
|---|---|
| 4—Solen. | 5—Solen. |
| 2—Solen, Polychaete. | 1—Solen, Portunus. |
| 1—Solen, Polychaete, Echinid. | 2—Gonoplax. |
| | 1—Nephrops. |
| | 1—Crab. |
| | 1—Gephyrean worm. |
| | 3—Empty. |

14th June, 1906.—Tremadoc Bay. Catch: 15 plaice, 24 dabs:—

| 3 plaice. | 6 dabs. |
|---|---|
| 1—Solen, Mactra. | 1—Solen. |
| 1—Mactra. | 1—Solen, Mactra. |
| 1—Polychaetes. | 1—Portunus. |
| | 1—Portunus, Nereids. |
| | 1—Nephrops. |
| | 1—Compound ascidians. |

19th June, 1906.—Aberporth Bay. Catch: plaice, dabs:—

12 dabs.

4—Ophiurids (stomachs very full).
1—Ophiurids, Pagurus, Scrobicularia.
1—Scrobicularia, Aphrodite.
1—Scrobicularia, Nucula.
1—Scrobicularia.
1—Pagurus, Scrobicularia, Natica, Aphrodite.
1—Pagurus.
1—Aphrodite, Scrobicularia.
1—Ampelisca (stomach full).

9th July, 1906.—Near Nelson Buoy. Catch: 320 plaice, 126 dabs:—

| 12 plaice. | 10 dabs. |
|---|---|
| 1—Solen. | 1—Tubicolous polychaetes. |
| 1—Nucula. | 1—Tubicolous polychaetes, Nucula. |
| 1—Tubicolous polychaetes. | 1—Ophiurids. |
| 3—Tubicolous polychaetes, Scrobicularia. | 3—Ophiurids. |
| 1—Tubicolous polychaetes, Scrobicularia, Nucula. | 1—Ophiurids, Nucula. |
| 3—Tubicolous polychaetes, Nucula. | 1—Holothurian, Pectinaria. |
| 1—Tubicolous polychaetes, Scrobicularia, ophiurids. | 1—Portunus. |
| 1—Empty. | 1—Empty. |

10th July, 1906.—Off New Quay. Catch: 8 plaice, 16 dabs:—

| 3 plaice. | 6 dabs. |
|---|---|
| 3—Polychaetes. | 2 Upogebia. |
| | 2—Hermit crabs. |
| | 1—Ophiurids. |
| | 1—Empty. |

13th July, 1906.—Llandudno Bay. Catch: 16 plaice, 84 dabs:—

| 12 plaice. | 12 dabs. |
|---|---|
| 6 Scrobicularia, Nereids. | 3—Sabella. |
| 3—Nereids. | 3—Sabella, sprats. |
| 2 Nereids, Echinocyamus. | 2—Sprats. |
| 1—Solen. | 1—Sprats, Crangon. |
| (Little food in any stomach). | 1—Sprats, Actinia. |
| | 2—Portunus. |
| | (Stomachs full.) |

19th September, 1906.—Red Wharf Bay. Catch: 5 plaice, 24 dabs:—

| 3 plaice. | 21 dabs. |
|---|---|
| 3—Scrobicularia. | 3—Ophiurids. |
| | 1—Ophiurids, Solen. |
| | 1—Ophiurids, Scrobicularia. |
| | 1—Ophiurids, Hermit crab. |
| | 1—Ophiurids, Crangon. |
| | 1—Ophiurids, Ampelisca, Hermit crabs, Echinus. |
| | 2—Scrobicularia, Ampelisca. |
| | 1—Ampelisca, Ophiurids. |
| | 1—Ampelisca, Hermit crab, Ophiurids. |
| | 2—Hermit crabs. |
| | 1—Crangon. |
| | 1—Carcinus. |
| | 5—Empty. |

20th September, 1906.—Entrance to Formby Channel. Catch: 22 plaice, 150 dabs.

| 8 plaice. | 11 dabs. |
|---|---|
| 2—Scrobicularia. | 1—Tubicolous worms. |
| 2—Scrobicularia, Polychaetes. | 2—Tubicolous worms, Mactra. |
| 2—Ophiurids, Polychaetes, Mactra. | 1—Tubicolous worms, Venus. |
| 1—Polychaetes, Mactra. | 2—Tubicolous worms, Portunus. |
| 1—Empty. (Very little food in stomachs.) | 1 Tubicolous worms, Carcinus. |
| | 1—Natica. |
| | 1—Nereids. |
| | 1—Sprat, Ophiurids. |
| | 1—Sprat, crab. (Stomachs full.) |

2nd October, 1906.—Luce Bay. Catch: 88 plaice, 14 dabs.

| 22 plaice. | 4 dabs. |
|---|---|
| 10—Solen. | 1—Arenicola. |
| 1—Solen, Nereids, Ampelisca. | 1—Portunus. |
| 2—Solen, Nereids. | 1—Nephrops. |
| 1 Solen, Ampelisca. | 1—Philine, Tube worm. |
| 2 Solen, Nucula, Mactra, Crab. | |
| 3—Nereids. | |
| 1 Nereids, Ampelisca | |
| 1—Arenicola. | |
| 2—Empty. | |

2nd October, 1906.—Luce Bay. Catch: 21 plaice, 21 dabs:—

| 6 plaice. | 6 dabs. |
|---|---|
| 6 —All Solen. | 1 Solen. |
| | 1—Solen, Pandalus. |
| | 1—Solen, Ophioglypha. |
| | 1 Solen, Crab. |
| | 1—Philine. |
| | 1—Gasteropod foot. |

2nd October, 1906.—Luce Bay. Catch: 184 plaice, 37 dabs:—

| 7 plaice. | 14 dabs. |
|---|---|
| 1—Solen. | 1 Solen. |
| 1—Solen, Nucula. | 3—Ophioglypha. |
| 1—Solen, Nucula, Nereids. | 1—Ophioglypha, Scrobicularia. |
| 1—Solen, Nucula, Nereids, Scrobicularia. | 1 Ophioglypha, Scrobicularia, Thracia. |
| 1—Nucula. | 1—Ophioglypha, Carcinus. |
| 1—Nucula, Nereids. | 1—Ophioglypha, Cardium echinatum. |
| 1 Nucula, Scrobicularia. | 1—Scrobicularia, Crab. |
| | 2 —Hermit crabs. |
| | 1—Portunus. |
| | 1—Philine. |
| | 1—Nemertine. |

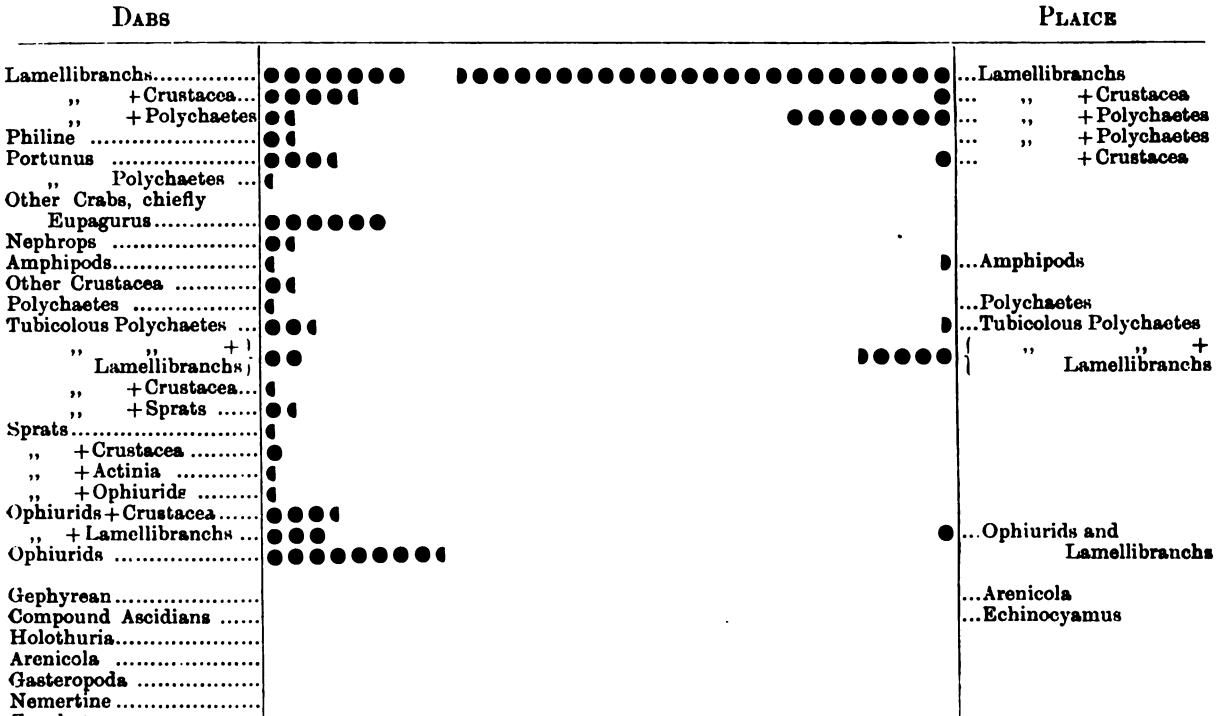
5th November, 1906.—Catch: 41 plaice, 32 dabs:—

| 12 plaice. | 15 dabs. |
|---|---|
| 10—Solen. | 4—Solen. |
| 2—Solen, Crab appendages. | 1—Solen, Nereids, Hermit crabs, Zoophytes. |
| | 1—Hermit crabs, Solen. |
| | 1—Hermit crabs, Amphitrite. |
| | 1—Hermit crabs, Solen, Pecten. |
| | 1—Zoophytes, Solen. |
| | 1—Portunus. |
| | 1—Soft crab. |
| | 4—Empty. |

22nd November, 1906.—Near Nelson Buoy. Catch: 10 plaice, 10 dabs:—

| 9 plaice. | 7 dabs. |
|---|---|
| All empty. | All empty. |

It is, of course, only practicable to display these observations in a roughly quantitative manner. The actual numbers of food animals present in the alimentary canal of each fish were not counted, and only approximate estimates of the abundance of each constituent of the food were made. It is, nevertheless, possible to shew roughly what is the commonest food of each fish. In the following table the numbers of black dots represent the number of fishes in which the food animals noted in the adjoining columns occurred exclusively. Each full dot represents two fishes.


DABS
PLAICE
Lamellibranchs
,, +Crustacea
,, +Polychaetes
Philine
Portunus
,, Polychaetes
Other Crabs, chiefly Eupagurus
Nephrops
Amphipods
Other Crustacea
Polychaetes
Tubicolous Polychaetes
,, ,, + Lamellibranchs
,, +Crustacea
,, +Sprats
Sprats
,, +Crustacea
,, +Actinia
,, +Ophiurids
Ophiurids+Crustacea
,, +Lamellibranchs
Ophiurids
Gephyrean
Compound Ascidians
Holothuria
Arenicola
Gasteropoda
Nemertine
Zoophytes
...Lamellibranchs
... ,, +Crustacea
... ,, +Polychaetes
... ,, +Polychaetes
... +Crustacea
...Amphipods
...Polychaetes
...Tubicolous Polychaetes
,, ,, + Lamellibranchs
...Ophiurids and Lamellibranchs
...Arenicola
...Echinocyamus

When arranged in this way the contrast between the food of plaice and dabs is at once evident. We see (1) that the dab is an omnivorous feeder and that it will take anything on the sea bottom from a sprat to a zoophyte; but that (2) it indicates a preference for particular food animals such as ophiurids, crabs and lamellibranchs. The latter were usually *Scrobicularia alba*, *Mactra*, *Tellina*, and often the feet of *Cardium echinatum*. The crabs were either *Portunus depurator*, which often occurred alone in the alimentary canal, *Carcinus moenas*, which was less common, or *Eupagurus bernhardus*, which was, perhaps, the commonest crab found as the food of the dab. The ophiurids were nearly always *Ophiura albida*. The Amphipods were always *Ampelisca*. Sprats were, of course, an unusual food, but on one occasion (in Llandudno Bay, on 13th July, 1906), two dabs were found which were gorged with small sprats. The tubicolous Polychaetes were either *Sabella* or *Amphitrite*. *Upogebia*, a Callianassid Crustacean, which so far we have only found in the stomachs of fishes, was found in two dabs taken on 10th July, 1906, off New Quay Head.

At the foot of the first column in the table are given several animals which occurred exceptionally in the stomachs of dabs examined from various grounds. They were generally associated with other food animals and never occurred in abundance. They indicate further the catholicity of taste of the dab.

The plaice affords a decided contrast. It will be seen that by far the commonest food animals of this fish were lamellibranch mollusca. Next in importance come Polychaete worms which very seldom, apparently, afford an exclusive food for the plaice, but are nearly always associated with lamellibranchs. Both errant and tubicolous polychaetes are eaten. The former are

usually Nereids, and the latter are often *Sabella* and *Pectinaria*. Ophiurids afford a very exceptional food for the plaice. Once or twice *Echinocyamus pusilla* was found, but in association with other animals, usually lamellibranchs. The commoner lamellibranchs are, of course, those eaten by the plaice. The following table represents the order of abundance in which these animals occurred in plaice stomachs:—

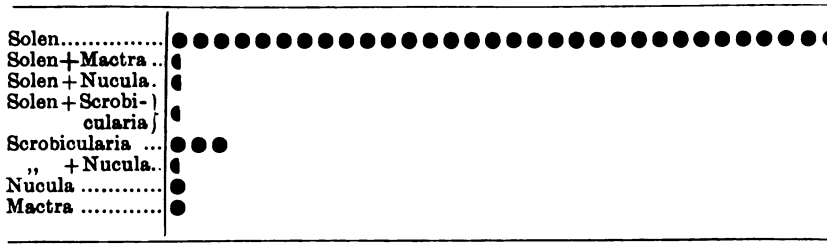



Fig. 24. Food of plaice.

The distribution of plaice and dabs, considered as a bionomic problem is, of course, one which would require much more patient and serious investigation than we have yet been able to attempt. In the consideration of the commoner food animals eaten by each species there is, however, a probable explanation of the comparative ubiquity of the dab as compared with the plaice. The latter is much more fastidious in its tastes than the dab, and when the common bivalve molluscs, which it always prefers, are not present on a fishing ground, or are sanded up, or disappear from any other cause, the plaice deserts this ground in favour of others where these molluscs are to be found. So we find that a "strike," or settlement of the spat of mussels, or other lamellibranchs on any fishing ground is often followed by an extensive immigration of plaice to this spot. Fishermen credit the plaice with the possession of some occult power of detecting the

presence of abundant bivalve food, even at considerable distances, but the reason of these aggregations of plaice on sea bottoms where there is for a time an abundant young lamellibranch fauna is simply this, that plaice are always to some extent moving about, except perhaps during one or more of the colder winter months, and when they encounter accidentally such an abundance of their favourite food they remain in the place where this is to be found deserting it when the food becomes scarce.

On the other hand, the dab, being a greedier feeder, and one accustomed to "take what it can get," finds a more or less abundant table spread for it on almost any of the shallow-water fishing grounds off our coasts. So we find that the dab is much more widely distributed than the plaice, and that when we cannot fish the latter the dab is generally to be obtained.

The sole is again more fastidious than either plaice or dab. The stomachs of these fish caught on the "John Fell" have been examined very often, but the results are not tabulated. One finds, however, that it is comparatively rarely that soles have any food animals in their stomachs other than Polychaete worms. In the varying abundance of the latter we have then one of the causes of the migrations of the sole. Of course, this is not the only cause, but, no doubt, it is one of the most important.

Finally I give the records of the examination of the stomachs of several cod caught during the early part of the year. They shew little beyond what we already know, viz., that the cod feeds largely on fish and crustacea.

## Cod.

9th January, 1906.—Beaumaris Bay. One specimen, 33ins. long. Contents of the stomach were:—

3 dragonets;
1 poor-cod;
1 small pleuronectid.

3rd January, 1906.—Blackpool Closed Ground. One specimen, about 33ins. long. Stomach contents:—

33 sprats (or young herrings, species indeterminable).
1 pleuronectid, 8ins. long;
3 pleuronectid, 3ins. long;
6 shrimps;
1 Aphrodite;
1 piece of coal.

24th January, 1906.—Beaumaris Bay. One cod, 30ins. long. Stomach contents:—

6 Carcinus.

31st January, 1906.—Red Wharf Bay. 1 cod, 30ins. long. Stomach contents:—

6 Hermit crabs.

31st January, 1906.—Near Liverpool N.W. Light Ship. Cod, 27ins. long. Stomach contents:—

1 whiting, 10ins long.

Cod 22ins. long. Stomach contents:—

7 Portunus.

Codling, 9ins. long. Stomach contents:—

9 Portunus.

1st February, 1906. Near N. Constable Buoy. Cod 32ins. long. Stomach contents:--

2 flat fishes, 6 to 8ins. long;
1 dragonet;
15 Portunus.

20th February, 1906.—Shoals. Cod, 33ins. long.

1 dragonet;
15 Portunus.

20th February, 1906.—Shoals. Cod, 33ins. long. Stomach contents:—

1 poor-cod, much fish debris.

Cod 28ins. long. Stomach contents:--

8 Portunus;
1 small whiting.

Cod 28ins. long. Stomach contents:—

7 Nephrops.

# REPORT ON VARIOUS BACTERIOLOGICAL ANALYSES OF MUSSELS FROM LANCASHIRE AND WALES.

By Jas. Johnstone.

## 1.—On the Bacteriological Analysis of Mussels from St. Annes-on-the-Sea.

At the last meeting of the Scientific Sub-Committee in May, 1906, instructions were given to make a bacteriological examination of the mussels on the bed near St. Annes. Accordingly on June 6th, 1906, Dr. Jenkins, Mr. J. Wright and I visited the locality in question and I then collected a sample for analysis.

The sewer at St. Annes is an iron pipe 24 inches in diameter which runs out over the foreshore to the low water mark of ordinary spring tides, and discharges some distance North of the town into the channel known as North Channel or Hollow. The flow of sewage through the pipe is continuous and there is delivered every 24 hours approximately 227,800 gallons (= 25 gallons per head of population). The sewage is quite untreated.

The mussel bed is situated near to, and indeed round, the sewage outfall, and some little distance to the South of the latter. It is a small bed but the mussels on it are fairly abundant. The shellfish are of good quality, with fine, clean and thin shells, apparently rapidly growing fish. Those examined were apparently well-nourished and healthy molluscs. The ground was, at the time when I collected the sample, fairly hard and clean. There were quite a number of starfishes on the bed, and to the presence of these animals is to be ascribed the unusual

number of empty shells present on the ground at the time. We looked for paper or other naked-eye evidence of sewage deposits on the bed but could see little traces of such matter.

This bed has long had an evil reputation and I am informed by Dr. F. Booth, Medical Officer of Health for the Urban District of St. Annes, that though he has no direct evidence of illness in St. Annes resulting from the consumption of these mussels, the Medical Officer of Blackpool has attributed several cases of enteric fever directly to the consumption of mussels from this bed. Unfortunately there is also grave reason for suspecting the cockles from the adjacent foreshore. It is apparently the case that cockles clean themselves of ingested sewage bacilli much less readily than mussels (Klein). That is, these micro-organisms find a more suitable *nidus* in the tissues of the cockle than in those of the mussel.

I think the direction of the tidal streams favours the contamination of these mussels. Not only is there direct and continual pollution by the St. Annes sewer, but a considerable quantity of greatly diluted sewage from Lytham and even from the Ribble Estuary generally, must find its way over these grounds at the earlier period of the ebb-tide. It is true that St. Annes sewage must pass out to sea through the North channel after the higher sand banks have become bared by the ebb, but it is also probable that, with the first of the flood some at least of this sewage may find its way back through the same channel on to the mussel bed. The topography of the coast, indeed, renders it impossible that these shell-fish can escape direct contamination.

The sample of mussels for examination was collected about 5 p.m. on 6th June. The mussels were collected from every part of the bed and at once placed in a recently

sterilised, tightly closing paint tin. They were taken back to Liverpool on the same evening and the unopened tins were at once placed in a sink and packed round with fragments of ice. The lids of the tins were tightly closed to prevent ingress of the water resulting from the melting of the ice. Every precaution was thus taken to prevent multiplication of the micro-organisms contained in the shellfish during the interval between collection and analysis. When the tins were opened next day the valves of the mussels were still tightly closed; in the meantime not all the ice had melted.

The primary inoculations were made in the forenoon of June 7th, within 20 hours after collection of the sample. Ten mussels were selected at random from the entire sample. The outside of the shell of each was rapidly washed with tap water (Liverpool water is free from sewage bacteria). The mussel was then opened with a sterile instrument; a slit with a sterile knife was made through the visceral mass into the stomach, and then about 1/10th cc. of the liquid in the latter cavity was withdrawn in a recently-drawn-out glass pipette. This was evenly spread over the surface of a recently poured plate of Grünbaum's neutral-red, bile-salt, lactose agar. At the same time a similar quantity of liquid was taken up in the same pipette and inoculated in a recently boiled tube of sterile milk; a different pipette was used for each mussel. The plates were incubated for 24 hours at a temperature of 42°C. The milk tubes were heated to 78°C. for 20 minutes to destroy vegetative forms of bacteria, and they were then incubated for 24 hours at 42°C. under anaerobic conditions (in an atmosphere of hydrogen).

The results of the primary surface inoculations on the neutral-red agar are given below:—

| Mussel. | No. of Colon-like Colonies. | White Colonies. |
|---|---|---|
| 1 | 170 | 12 |
| 2 | 80 | 4 |
| 3 | 36 with 2 diffuse red patches | 7 |
| 4 | 15 with numerous red patches | 1 |
| 5 | 76 with many diffuse red patches | 1 |
| 6 | 132 with several diffuse red patches | 3 |
| 7 | 28 with 5 diffuse red patches | — |
| 8 | 39 with several diffuse red patches | numerous |
| 9 | 32 with numerous diffuse red patches | — |
| 10 | about 320 | — |

The significance of these results is that unpolluted mussels or oysters taken far out at sea contain no bacteria in their stomachs which grow on neutral-red agar.

This is also true of non-sterile but uncontaminated sea water. The great majority of the organisms growing on this medium are such as are found in sewage, and indeed are those that have their normal habitat in the human intestine.

The diffuse patches are formed by the fusion of numerous "colon-like" colonies.

The object of the anaerobic milk cultures was to demonstrate the presence of a spore-forming anaerobic bacillus—the *B. enteritidis sporogenes* of Klein, or a nearly related form. All the ten cultures made gave positive reactions; that is, the milk was curdled and abundant gas formation took place, breaking up the curd in the characteristic manner. This again is presumptive evidence of sewage pollution since unpolluted shellfish and unpolluted fresh or sea water do not readily give this reaction.

*Bacillus coli*, the presence of which is now regarded as indicative of sewage pollution, grows on neutral red agar as deep red, and large colonies. Not all these "colon-like" growths are, however, produced by the typical *B. coli*. Eleven of these colon-like colonies were, therefore, selected from the ten plates, and from them pure sub-cultures were made on nutrient agar. After 24 hours incubation at 42°C. these secondary cultures were examined in detail. The presence or absence of motility of the bacilli was observed microscopically, and each sub-culture was inoculated in 7 different media (bile salt glucose broth, glucose broth, lactose broth, mannite broth, cane sugar broth, glycerine broth, and litmus milk). These tertiary sub-cultures were again incubated for 48 hours at 42°C.

At the end of this time six gave the reactions for the typical *Bacillus coli*. Therefore, about one-half of the discrete colonies identified as "colon-like" proved to be those of *B. coli*.

Neutral-red, bile-salt lactose agar not only affords an easy means of picking out organisms which are probably *B. coli*, but it also distinguishes these from organisms belonging to the Gaertner and typhoid groups. These latter grow on the medium in question as white

translucent colonies. Particular attention was paid to these latter organisms and eight were selected and examined in pure sub-culture as in the case of the "colon-like" colonies.

Most of these colonies were those of aberrant organisms which could not be identified. Two of them gave most of the reactions characterising Gaertner's bacillus, and may possibly have been this microbe. One of them, however, (isolated from mussel No. 2), was of much greater significance, and had the following characters:

1. It formed a round, slightly raised, translucent colony on neutral red, bile-salt, lactose agar.
2. It was motile.
3. It formed acid only in bile-salt broth.
4. Formed acid in glucose broth.
5. Slightly discoloured lactose broth.
6. Formed acid in mannite broth.
7. Gave no reaction with cane sugar broth.
8. Formed acid in milk.

The agglutination test was made for me by Mr. Lewis of the Pathological Department at Liverpool University. Twenty-nine parts of an emulsion of the bacillus were mixed with one part of a serum taken from a patient suffering from enteric fever, and which gave a positive result with a known strain of *Bacillus typhosus*. This was kept under observation for half an hour. At the end of this period well-marked clumping of the bacilli took place.

All these reactions are characteristic of *Bacillus typhosus* the specific germ of enteric fever and I think it highly probable, therefore, that this microbe was present in mussel No. 2.

It is only in comparatively few cases that *B.*

*typhosus* has been isolated from shellfish, though there is little doubt that it is often present. The microbe is one which possesses little vitality in sea water (Herdman and Boyce), or in the alimentary canal of the mussel or oyster (Klein), and its presence, therefore, indicates recent, and therefore, dangerous pollution, a result which is indeed apparent from the unusually large numbers of *Bacillus coli* present in the mussels examined.

A quantitative analysis of the bacteriology of the mussels was also made (as regards *B. coli*) by the method of decimal dilutions of Dr. A. C. Houston, Bacteriologist to the Royal Commission on Sewage Disposal. Five mussels were taken and removed from their shells with sterile precautions. The liquid from the shell cavaties was made into an emulsion with the bodies of the shellfish and this emulsion was made up to the volume of 500 cc. with sterile water. 1 cc. of this liquid, therefore, contained 1/100th part of one mussel. The liquid was then diluted so that 1 cc. contained 1/1,000 part of one mussel and the process was repeated. In this way emulsions were obtained which contained:—

A. 1/100 part of a mussel.

B. 1/1,000 part of a mussel.

C. 1/10,000 part of a mussel.

D. 1/100,000 part of a mussel.

1 cc. of each was then inoculated on neutral red agar as before, and also in milk under anaerobic conditions.

A contained about 20 colon-like organisms.

B ,, ,, 6 ,, ,,

C ,, ,, 2 ,, ,,

D was sterile.

One of the colonies in C was produced by *B. coli*. This organism was, therefore, present in 1/10,000 part of a mussel (average of five examined).

The enteritidis reaction was given only by emulsion A.

*B. coli* was, therefore present in 1/10,000 part of a mussel but was absent in 1/100,000 part.

I think that the above results leave no room for doubt that the mussels from the bed near the St. Annes Sewage Outfall are most gravely polluted by micro-organisms of intestinal (or faecal) origin.

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## 2.—Report on an Examination of the Mussel Beds at Morecambe.

An analysis of mussels from the "Ring-Hole," Morecambe, was made in July of this year, and a Report was presented to the Chairman of the Joint Committee. That Report was only a preliminary one, and was only intended to show whether or not it was desirable to make a more exhaustive examination. It was evident that further enquiry was necessary, and on 15th September, at the time of the low spring tides, Mr. Scott and I visited Morecambe for this purpose. I desire here to state that every assistance was given to us by the Local Sanitary Authority, and that no information that we asked for was withheld. On this first visit we were accompanied by Alderman Thomas Baxter, Alderman Snowden, the Chairman of the Sanitary Committee, Councillor Miller, Inspector Lamb and Mr. E. Gardner, the local Fishery Officer. We saw the sewer outfalls and some of the mussel beds, and collected a number of samples from the vicinity of the main sewer outfalls, from "Baiting-Knot" Skear, and from Ring-Hole. These samples were taken at about 6 p.m., near the time of low water. Again, on 5th October, Mr. Scott and I made another visit to Morecambe and met Dr. Watterson, the

Medical Officer of the Borough. At this time the men were working on the outer Heysham Skears and we therefore visited the latter at 5 a.m., the time of low water on the morning tide. Further samples were taken from "Great-Out" and "Little-Out" Skears, and from Ring-Hole. Samples of sea-water were also taken from off Great-out Skear, from off Baiting-Knot, from over the main sewer outfall (at that time covered), and from Ring-Hole. On this visit we also saw the main sewage culverts and the purification works.

Bacteriological analyses of the shellfish so collected were made in the usual manner. The results show that *Bacillus coli* was present in practically all the mussels examined. But in no case was the degree of contamination considerable. There was a noticeable difference in the results obtained from this analysis and those from the analysis of July 19th. In this latter case the mussels (which we did not personally collect) were apparently not a representative sample from the Morecambe mussel beds, although they may have been taken from a place from which mussels are sent to the markets.

To describe a mussel as dangerously polluted merely because it contains *Bacillus coli* would be quite unjustifiable. This microbe is not, in such circumstances, so far as we know, dangerous to health. Its presence in a shellfish merely indicates that the latter is living in sea-water which is exposed to some degree of sewage contamination. Its presence always indicates the *possibility* that the shellfish in which it is found may, under certain circumstances, come to harbour microbes of a nature strictly pathogenic, such as the typhoid bacillus. But when the number of *B. coli* in a mussel is few then this possibility is remote. When the number is large, or when the pollution is notorious (as in such cases as those of the

mussels at Egremont, Rock Ferry, or St. Annes) then we may reasonably conclude that the shellfish should not be used for human food. In every sample of mussels from the coasts of Lancashire, Cheshire and Wales examined so far, *Bacillus coli* has been found; and much more extensive investigations carried out by the Sewage Commission with reference to oysters have given the same result. "If," say the Commissioners, "it should be seriously contended that the *mere presence* of B. coli or coli-like microbes in an oyster should condemn it, few oysters would probably escape condemnation." Probably the same conclusion holds good for mussels also.

At the present time about 90 per cent. of the sewage of Morecambe is treated by the biological or septic method of purification. The remainder passes into the sea as crude sewage. There can be no doubt that the presence of this crude sewage is objectionable, but I am assured that, in a short time, all the Morecambe sewage will pass through the septic tanks. There is some diversity of opinion among bacteriologists as to how far this method of treatment of crude sewage removes the danger to health which might be incurred should the effluent go near a shellfish laying. But the general opinion is that the chance of dangerous bacteria (such as *Bacillus typhosus*) finding their way into the effluent is greatly lessened.

This is specially the case when the effluent is very largely diluted with sea water before reaching shellfish beds. When the present Morecambe sewerage scheme was sanctioned by the Local Government Board, this was apparently considered, for the main sewage outfall is so situated that the effluent is carried well out to sea and is enormously diluted on the ebb tide before coming near the mussel beds. Shellfish are dangerous to health when they

contain toxic quantities of *Bacillus typhosus* (producing enteric fever), or possibly *B. enteritidis* (producing Gaertner poisoning). These organisms must, in any circumstances, if they are present at all, always be present in sewage in small numbers; and when the latter is intercepted in storage culverts and septic tanks, and then turned into the sea and greatly diluted, the chance that a mussel can be dangerously infected becomes very small.

Most people will say that neither crude sewage, nor a purified effluent, should find its way anywhere near a shellfish bed. One must agree with this opinion, but it is rather to be regarded as a "counsel of perfection." When practicable methods of sanitary engineering and sewage disposal are being considered, and when one thinks of such a densely populated littoral as that of Lancashire, it must be apparent that the ideal of removing sewage so that it cannot approach mussel beds is quite unattainable.

The general conclusion, then, is that the mussels from the skears and beds at Morecambe are not polluted to such an extent as to constitute serious danger to the health of those consuming them for food. In view of the importance of the interests involved, I give below the evidence on which this opinion is based.

**The Morecambe Sewage System.**

The accompanying chart shows the positions of the mussel beds and the sewer outfalls. Altogether six sewers empty into the Channel. No. I., which lies to the West of the West End Pier, is the main sewer, and carries seawards the treated effluent from the purification works. It is a 24-inch iron pipe, and terminates near the skear called "Seldom Seen," at the low water mark of spring tides. No. II., the "Midland Culvert," is situated to

the East of the old harbour; it serves the Winter Gardens, the Midland Hotel, and a small group of houses near this. No. III., the "Queen Street" sewer, runs out obliquely from Queen Street, near the Central Pier. Nos. IV. and V., the "Calton Terrace" and "Thornton Road" sewers, lie to the East of the Central Pier. No. VI., the "Bare Sewer," is not shown on the chart; it serves the township of Bare. Nos. II. to VI. deliver crude sewage, and Nos. III. to VI. are 12-inch iron pipes. They all terminate at low-water mark of ordinary tides.

Taking a normal population of 11,000 and an average water supply of 20 gallons per head per 24 hours, we find that the main sewer outfall delivers 200,000 gallons of purified sewage, and the other outfalls, 20,000 gallons of crude sewage per 24 hours.

Probably the contribution of the Old Harbour to the pollution of Ring-Hole may be neglected. At the present time the Harbour is strictly private ground, and is used only for breaking up old warships and other superannuated vessels. It is largely silted up, and though the bottom at low water looks exceedingly foul, it is probable that this foulness is more apparent than real. At any rate, the only sewage matters issuing from it are those produced by the workmen employed on the vessels. As a source of pollution the Old Harbour does not count for much, and whatever evil exists could easily be remedied.

Sewers II. to VI. represent the outfalls of the original Morecambe sewerage system before the new scheme was brought into operation. For some years prior to 1897 the Local Government Board had urged on the Borough Council the desirability of adopting a system of sewage purification. In 1897 they expressed the opinion "that untreated sewage should not be discharged anywhere in Morecambe Bay," an ideal which, except at Morecambe,

the Local Sanitary Authorities have not yet attempted to realise. In 1898 Mr. H. Bertram Nichols, C.E., designed the present system of sewerage. At that time the Cameron method of septic purification was in high favour, and it was decided to adopt this. The scheme provided for the collection and treatment of the sewage (almost entirely domestic) of Morecambe, Bare and Torrisholme—an estimated population of 11,000, with an annual influx of 30,000 visitors—at an estimated total cost of £60,000. Really the system was designed to cope with a population of 60,000 persons, and for an average daily water supply of 20 gallons per head. The main sewers are laid along the back of the town, and terminate in two main outfalls, iron pipes of 21-inch and 24-inch diameter respectively. These open into two culverts, which are designed to contain an aggregate night flow of 400,000 gallons. The culverts open into a well, and the sewage, after being screened so as to remove solid matters, is raised by means of four centrifugal pumps worked by electric power to the level of the channels leading into the septic tanks.

There are eight rectangular tanks, each of which is covered in and airtight. After passing through a "detritus chamber," in which much of the grit from road washings is allowed to settle, the sewage passes through special inlet pipes into the tanks themselves. Here it is allowed to remain, and the well-known septic process of purification goes on. The saprophytic and nitrifying bacteria normally present in the stale sewage act on the organic matters present, and most of the solids present in suspension pass into a state of solution. Organic matter is broken down and resolved largely into harmless nitrites and nitrates. A certain amount of sludge settles at the bottom of the septic tanks, but the rate of accumulation of this is very

slow, and the tanks require to be cleaned out only at very long intervals. The result is the production of an effluent which, if the tanks are properly worked, is almost clear, is non-putrescible, and which does not cause a nuisance. The effluent after leaving the septic tanks passes into an underground storage culvert which has a storage capacity of 800,000 gallons. At the outlet end of this storage culvert is a penstock chamber and a chamber provided with a tidal valve. The culvert discharges into a 24-inch iron pipe, the liquid in which is under pressure from the head of sewage in the culvert. The culvert was designed to remain full, or partially full, of effluent for nine hours, and to discharge in three hours. In actual practice the sewer outfall is opened three hours after, and closed four hours before high water.

The main outfall sewer runs out over the sands to a point at Seldom Seen Skear at the low-water mark of spring tides and there discharges. At Morecambe the duration of the ebb is much greater than that of the flood. At spring tides the flood lasts for 3 hours and 15 minutes on the average, and at the neaps for 4 hours and 45 minutes. Extensive float experiments were carried out to determine how far the sewage would be carried by the ebb before the tide turned.* Drift bottles, and large wooden floats provided with flags so that their movement could be observed, were used. The information derived from these float tests showed that the sewage would be carried well out to sea before the turn of the tide, and would not return to Morecambe. Many of the bottles

*The Engineer's report is:—"From information derived from the float tests on the 10th February, and 16th and 23rd March, 1897, and between 25th of August and the 3rd September last (1898), there is no doubt that the best point of discharge is at "Seldom Seen," a point on the north side of the fishing baulks lying north of the Battery Inn. At this point the tide at half-ebb would be sufficient to carry away the sewage coming from Morecambe far out to sea before the tide turned."

were carried out of the Bay entirely and were found at Drigg, on the Cumberland coast. Others went over to Grange, and, no doubt, after oscillating for some time on the ebb and flood would ultimately leave Morecambe Bay. Whatever way the sewage finally went, the dilution in Heysham Lake and the Lune would be enormous. Comparative analyses of the sea-water on the ebb and flood would show, I think, that sewage bacteria though found in the ebb, in the Morecambe Channels, would be absent, or at least very few, in the ensuing flood. It was intended to make these analyses, but the work was too extensive in scope to be undertaken at the time. Such comparative determinations of the numbers of bacilli in sea-water have been made in various places, as, for instance, in the estuary of the Thames and in Kiel Harbour, and the results are both interesting and practically important.

**Bacteriological Analyses.**

On the occasion of our first visit six samples were collected. Two were taken from near the main sewer outfall, two from Baiting Knot, and two from Ring-Hole. All the samples, with one exception from the top of Baiting Knot, were raked by Mr. Ed. Gardner by means of the "long craam." In each sampling several drags were made, and the total sample was mixed and about a dozen mussels put into a sterilised tin. The tins were placed in ice until the analysis was made (some twelve hours afterwards). Four mussels were then selected at random from each sample--24 in all, and about $\frac{1}{10}$ cc. of the stomach contents of each was plated on neutral-red, bile-salt, lactose agar (Grünbaum's medium). After 48 hours' incubation at 42°C. the plates were examined. Each alternate mussel was also examined for the presence of anærobic spore-bearing bacilli.

The results of these primary inoculations are shown on the following table. It will be seen that the "enteritidis reaction" was typical in each of the 12 anærobic cultures made. The colonies which resembled those produced by *Bacillus coli* were counted, and the numbers present in $\frac{1}{10}$ cc. of the stomach juices of each shellfish vary from 14 downwards. On two of the plates no "colon-like" colonies were present. In some of the countings the number is to be regarded as a minimum one on account of the fusion of colonies.

## 1st Analysis.

### Primary Cultures on Neutral-red, Bile-salt, Lactose Agar Plates.

| Locality. | Mussel. | "Colon-like" Colonies. | White Colonies. | Enteritidis reaction. |
|---|---|---|---|---|
| Between "Seldom Seen" and "Reap" Skears. | 1 | 3 | numerous and fused. | + |
| „ | 2 | 4 | „ | |
| „ | 3 | 5 | 1 patch | + |
| „ | 4 | 3 several patches | 0 | |
| N. from "Reap" Skear. | 5 | 5 | 1 patch | + |
| „ | 6 | 4 | large patches | |
| „ | 7 | 4 | 0 | + |
| „ | 8 | 2 | many patches | |
| N. Side of "Baiting Knot." | 9 | 3 | 0 | + |
| „ | 10 | 8 | 2 | |
| „ | 11 | 1 | 2 | + |
| „ | 12 | 3 | 0 | |
| From top of "Baiting Knot." | 13 | 0 | numerous fused colonies | + |
| „ | 14 | 3 | 0 | |
| „ | 15 | 0 | many patches | + |
| „ | 16 | 0 | several patches | |
| N. Side of "Ring Hole." | 17 | 5 patches | 0 | + |
| „ | 18 | 5 | 10 | |
| „ | 19 | 2 many fused | 0 | + |
| „ | 20 | 0 | several patches | |
| Top end of "Ring Hole." | 21 | 7 | 0 | + |
| „ | 22 | 4 | numerous and fused. | |
| „ | 23 | 9 | 0 | + |
| „ | 24 | 14 | 0 | |

Thirteen of the colonies identified as belonging to the colon group were then subcultured on nutrient agar in sloped tubes, and after 48 hours' incubation these growths were subcultured in bile-salt broth, glucose, lactose, mannose, and cane sugar broths, and in litmus milk. Again, after 48 hours' incubation the cultures were examined. The results of these tertiary subcultures are shown on the next table. It is obvious that the colonies Nos. 6 and 14 are not those of *B. coli.* In two cases (7 and 11) the bacilli were non-motile, and in three cases (1, 6, 7,) the motility was very feeble. But at least six out of the thirteen colonies examined in detail proved to be those of typical *B. coli.*

The white colonies present on the primary plates did not belong to bacteria possessing any special significance.

### 1st Analysis.

### Results of Tertiary Subcultures from Primary Plates.

| Mussel. | Bile-Salt. | Glucose. | Lactose. | Mannose. | Cane Sugar. | Milk. | Motility. |
|---|---|---|---|---|---|---|---|
| 1 | a g | a g | a g | a g | o | a c | ? + |
| 2 | a g | a g | a g | a g | a g | a | + |
| 3 | a g | a g | a g | a g | o | a c | + |
| 6 | a g | a g | a g | a g | o | a c | ? + |
| 6 | a g | a g | o | a g | o | o | + |
| 7 | a g | a g | a g | a g | o | a c | + |
| 7 | a g | a g | a g | a g | a g | a c | — |
| 7 | a g | a g | a g | a g | o | a c | ? + |
| 7 | a g | a g | a g | a g | o | a c | + |
| 9 | a g | a g | a g | a g | d | a c | + |
| 11 | a g | a g | a g | a g | o | a c | — |
| 14 | a | a | a | a | o | a c | + |
| 23 | a g | a g | a g | a g | a g | a c | + |

Explanation of Symbols:—
a = acid; g = gas; c = clot; d = discolouration.

The second analysis was conducted in precisely the same manner. A sample of about 20 mussels was collected from Great-out and Little-out Skears, one mussel being taken from each part of the skears visited. This sample was therefore a thoroughly representative one. One drag was then made in the middle of Ring-Hole, and a similar quantity was taken from the sample. Five mussels from each of these samples were examined as before. In the case of the Ring-Hole shellfish the enteritidis reaction was not tried for. The results of these primary inoculations are shown on the next table. Distinctive white colonies were absent in each case, and the numbers of colon-like colonies vary from 20 downwards. In the case of two of the Outer Skear mussels the enteritidis reaction was atypical.

### 2nd Analysis.

### Primary Subcultures on Neutral-red, Bile-salt, Lactose Agar Plates.

| Locality. | Mussel. | "Colon-like" Colonies. | White Colonies. | Enteritidis re-action. |
|---|---|---|---|---|
| "Ring Hole" | 1 | about 20 | 0 | |
| „ | 2 | „ 20 | 0 | |
| „ | 3 | 14 | 0 | |
| „ | 4 | 9 | 0 | |
| „ | 5 | 7 some patches | 0 | |
| "Out" Skears | 6 | 4 | 0 | not typical |
| „ | 7 | 7 | 0 | + |
| „ | 8 | 16 | 0 | not typical |
| „ | 9 | 7 some patches | 0 | + |
| „ | 10 | 14 | 0 | + |

As before, a number of the colon-like colonies from the primary plates made from the Outer Skear mussels were subcultured. The results are given below in detail. It is evident that colonies 8, 9, 9, 10, 10, are not those of *B. coli*, while there are other four in which motility was not observed. Four colonies are those of typical *B. coli*. This is a lower proportion than was observed in the case of mussels taken from the skears higher up the Channel, and therefore nearer to the sewer outfalls. It is what one might expect to find. The contamination of the outer Heysham Skears is less than that of Baiting Knot and Ring-Hole. By the time that the sewage reaches the Heysham Skears it has become so greatly diluted that there is a much less chance of sewage bacteria being ingested by the shellfish. The percentage of microbes indubitably identified as *B. coli* is also less, an indication that the micro-organism undergoes some change as a result of its sojourn in sea-water, or perhaps perishes altogether.

### 2nd Analysis.

### Results of Tertiary Subcultures from Primary Plates.

| Mussel. | Bile-Salt. | Glucose. | Lactose. | Mannose. | Cane Sugar. | Milk. | Motility. |
|---|---|---|---|---|---|---|---|
| 6 | a g | a g | a g | a g | d | a c | + |
| 6 | a g | a g | a g | a g | d | a c | + |
| 7 | a g | a g | a g | a g | o | a c | + |
| 7 | a g | a g | a g | a g | o | a c | — |
| 8 | o | o | o | o | o | a c | + |
| 8 | a g | a g | a g | a g | o | a c | — |
| 8 | a g | a g | a g | a g | o | a c | + |
| 8 | a g | a g | a g | a g | o | a c | — |
| 9 | a g | a g | a | a g | o | a c | + |
| 9 | a | a | a | a | a | o | — |
| 10 | a | a | a | o | o | a c | + |
| 10 | a | a | o | o | o | o | + |

TERTIARY SUBCULTURES FROM BROTH INOCULATED WITH 1 CC. WATER.

| Locality. | Bile-Salt. | Glucose. | Lactose. | Mannose. | Cane Sugar. | Milk. | Motility. |
|---|---|---|---|---|---|---|---|
| "Out" Skeat | ... a g | ... a g | ... a g | ... a g | ... o | ... a c | ... — |
| "Baiting Knot" | ... a g | ... a g | ... a g | ... a g | ... d | ... a c | ... + |

It was not possible at the time to make an exhaustive analysis of the sea-water in the vicinity of the skears, but several samples were collected and examined. Sterilised glass-stoppered bottles were filled with water from off Great-out Skear, from just over the main sewer outfall, from near Baiting Knot, and from Ring-Hole. In the cases of the outer skears, and Baiting Knot, only one culture was made from each sample. One cc. of the water was added to bile-salt broth and the latter was incubated. A reaction was then obtained and plates were made from the primary culture. Colonies supposed to be those of *B. coli* were then selected, and examined in pure subculture. In the case of the Baiting Knot sample the colony selected was *B. coli*, but in the case of the colony from the outer skear sample motility was not observed. The microbes present were therefore not typical *Bacillus coli*.

In the case of the water sample from near the main sewer outfall, and from Ring-Hole, a number of dilutions were made, each $\frac{1}{10}$th less concentrated than the one immediately above. One cc. of the original or diluted liquid was put into a sterile Petri dish and neutral red agar at a temperature of 40°C. was poured in and allowed to solidify. After 48 hours' incubation the plates were counted. A dozen plates were made. Only primary inoculations were made. In the case of the water from

near the main sewer outfall 350 colon-like colonies were counted on the plate made from 1 cc. The plates made from ·001 cc. and the lower dilutions were sterile. In the case of the Ring-Hole sample 19 colon-like colonies were counted in the plate made from 1 cc. and 5 from that made from 0·1 cc. The lower dilutions yielded sterile plates.

These observations do not go very far, but they just indicate that the dilution of the effluent and the crude sewage is so very great that the bacteria present become enormously dispersed through the sea. This is indeed what one might expect from a consideration of the topography and tidal currents of the locality.

The results of these water analyses are shown on the following table:—

BACTERIOLOGICAL ANALYSIS OF WATER SAMPLES.

| Locality. | Amount taken. | Reaction in Bile-salt Broth. | No. of "Colon-like" Colonies on neutral-red agar plates. |
|---|---|---|---|
| Off "Great Out" Skear. | 1 c.c. | + | |
| Off "Baiting-Knot" | 1 c.c. | + | |
| "Ring-Hole" | 1 c.c. | | 19 |
| " | 0·1 c.c. | | 5 |
| " | 0·01 c.c. | | sterile |
| Above Sewer Outfall | 1 c.c. | | 350 |
| " | ·001 c.c. | | sterile |

## The Effect of the Septic Method of Treating Crude Sewage.

A further question remains to be considered in relation to the contamination of the Morecambe mussel beds, viz., the extent to which the biological or septic method of purification reduces the numbers of pathogenic bacteria which may possibly be present in the crude sewage. It will be admitted that the fact that most of the Morecambe crude sewage passes through septic tanks before reaching the sea must have its influence on the interpretation of the bacteriological results. The question of the harmful effects of contamination of the mussels by the effluent from the main sewer outfall in fact turns to some extent on what really happens in the septic tanks. Does the putrefactive process taking place there lead to the elimination of pathogenic bacteria? There are comparatively few observations on this subject, and I may refer here to the principal results obtained.

(1) Dr. A. C. Houston (Bacterial Treatment of Crude Sewage: Third Report: London County Council, No. 501, 1900), inoculated small quantities of unsterilised Crossness crude sewage with various pathogenic bacteria. The cholera bacillus was employed in two experiments, and a number of these vibrios greatly in excess of the number of other micro-organisms present in the sewage was added to 10 cc. of the crude liquid. In one experiment the bacillus lost its vitality in less than a fortnight; and in the other experiment was found in the sewage for nearly four weeks.

Tubes containing Crossness crude sewage were then inoculated with pure cultures of *Bacillus prodigiosus*. In one experiment the bacillus was not recognised in the liquid after sixteen days. Day by day the numbers of

this microbe decreased, showing that crude sewage was an unfavourable medium for its development. In the second experiment it remained alive for ten days, but was not discoverable afterwards.

*Staphylococcus pyogenes aureus*, a pathogenic microbe occasionally present in raw sewage, was then experimented with. It was found that this organism could persist in crude sewage for at least thirty-eight days. After that time it was no longer recognisable.

Houston's conclusions from these experiments is that the pathogenic bacteria dealt with are capable of retaining their vitality in crude sewage for a considerable time. But he also points out " that the number of the pathogenic germs added to the sewage in these experiments was vastly greater that could conceivably take place under natural conditions, and that, notwithstanding the enormous numbers introduced, there was definite indication of a somewhat rapid decrease in their numbers." (*Ibid.* p. 75.)

(2) MacConkey (Report Royal Commission on Sewage Disposal, 2 (cd.1178), 1902) determined the longevity of *Bacillus typhosus* in various sewage liquids, and found that this microbe did not find a suitable habitat in any of the liquids dealt with. Crude sewage was inoculated with the typhoid bacillus, and it was found that it died out rapidly. In one experiment it disappeared six days after the date of inoculation, and in another was not recognised after the lapse of thirteen days. Effluents from various septic purification processes were also employed, and it was found that these were even more inimical to the life of the bacillus than crude sewage. A portion of Cameron bed effluent (such as we have to deal with at Morecambe) was inoculated with typhoid bacilli to the extent of twelve millions per cc., and at the end of seven days the number of the bacilli had decreased to 200 per cc. MacConkey's

conclusions may be given in his own words:—"The fluids experimented on are inimical to the growth of the *Bacillus typhosus*, and if these pathogenic bacteria find their way into a bacteriological system of treatment they meet with conditions hostile to their multiplication. We know that typhoid bacilli must find their way into the sewage from the excreta of persons suffering from typhoid fever, but they cannot be present in large numbers, and in the various samples of crude sewage which we have examined we have not found any. Therefore it may be concluded that, allowing that these bacilli reach biological beds or septic tanks, they are present in such small numbers, and the conditions are so adverse to their existence, that they will not survive the treatment."

(3) Boyce, MacConkey, Grünbaum and Hill (Report Royal Commission Sewage Disposal 2 (cd. 1178, 1902), p. 87, determined the rate at which the bacilli present in the effluents from various septic processes disappeared when the liquid was filtered through sand or earth. The effluent from a Dibdin bed was passed through four feet of earth, and while flowing on to this filter great numbers of typhoid bacilli were added to it, so that the liquid contained much greater quantities than could possibly have been the case in nature. Twenty-four hours after being added to the filter the typhoid germs could not be detected in the liquid flowing from the former.

(4) These experiments are, however, rather artificial ones and perhaps greater weight is to be attached to an experiment made by Houston (Report Royal Commission Sewage Disposal, 4, Vol. 3 (cd. 1885), 1904, p. 77) with the object of determining to what extent pathogenic bacteria pass through septic tanks and filters. A Cameron tank and contact beds at Leeds were employed in these experiments. Enormous quantities of *Bacillus*

*pyocyaneus* (the microbe of green pus) were added to the sewage flowing into the septic tanks. The liquid in these was examined three hours after the inoculation and the mircobe was then found. The effluent from the contact beds was then examined, and it was found that *Bacillus pyocyaneus* was present in it immediately after the first emptying of the beds. Therefore, the Cameron method of treating sewage did not eliminate these particular microbes. It ought, however, to be remembered that they were present in the original sewage to a relatively enormous extent, and that results obtained from their use do not necessarily apply to the typhoid bacillus.

The conclusion of the Royal Commissioners on Sewage Disposal (Report 4, Vol. I (cd. 1883), 1904, p. xx) on this question may usefully be quoted here. "The treatment of sewage," they say, "according to methods at present in use, cannot be relied upon so to alter its character as to allow of its discharge in the immediate neighbourhood of shellfish layings without incurring considerable risks of disease being communicated by the consumption of shellfish taken from such layings. In such cases the sewer outfall must be removed or the layings closed. In other cases where (*e.g.*) the layings are at a considerable distance from the outfall, and the sewage would be largely diluted before reaching them, treatment of the sewage might be of value in diminishing risk."

In the case of the Morecambe mussel beds we have seen that this latter condition is satisfied in so far as the main sewer outfall is concerned. Given good administration, and supposing that the taking of shellfish from the immediate neighbourhood of the outfall is not practiced, then it appears that this enormous dilution of the effluent does take place. Danger (if such exists) is to be apprehended from the continued existence of the discharge of

crude sewage from the old outfall sewers. I am assured that it is the intention of the Borough Council gradually to connect up the private sewers opening into these main outfalls with the main sewerage system. Already the Queen Street and Calton Terrace sewer systems are in hand, and soon these will be discontinued. There remain then the Midland, Thornton Road and Bare sewer systems. These deliver the sewage from property equivalent to about 200 houses, say 1,000 persons, less than 10 per cent. of the estimated population. This sewage is not included in the present purification systems. When it is ultimately so included, there is no doubt that the present degree of risk would be largely minimised, perhaps practically removed.

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### 3.—Report on an Examination of the Mussel Beds in the Estuary of the Conway.

On August 15th, 1906, a preliminary report was made to the Scientific Sub-Committee on a bacteriological analysis of two samples of mussels sent to me from the estuary of the Conway. It was, however, considered desirable that a more exhaustive analysis and inspection should be made, and on October 17th Dr. Jenkins and I visited Conway for the purpose of seeing the mussel beds. We were accompanied by Dr. Fraser, Medical Officer of Health for the Carnarvon Combined Sanitary Districts, Professor White, of Bangor University College, and Mr. R. Jones, the Fishery Officer in charge of the District. On this occasion we saw most of the sewer outfalls, and also collected samples of mussels from various places, where men and women were working. Samples of water from the river were also taken. It was found impossible to finish the inspection on that day, and on October 26th

Mr. A. Scott and I landed from the "John Fell," met Mr. R. Jones, and saw the remainder of the sewer outfalls, and took further samples of mussels and sea-water. Finally, on October 30th, I visited Llandudno and saw the sewer outfalls there. I am obliged to Mr. Delamotte, Surveyor for the Borough of Conway, and to Mr. W. Little, Sanitary Inspector for Llandudno, for much assistance with regard to the inspection of the sewer outfalls.

The results of these visits, and those of the analyses made, show, I think, that there is some considerable degree of pollution in the mussels of the Conway Estuary, both from the river between the Bridges and Deganwy and from the Scars below the latter locality. The pollution is not excessive, and is far less than that found in mussels from some other places in the Lancashire and Western Sea-Fisheries District, as, for instance, Egremont in the Mersey; though it is greater than in some other mussel areas, as for instance, Morecambe. The area over which the mussel beds and the sewer outfalls are distributed is a comparatively small one, and the pollution is from crude sewage and is of recent origin. It is probable, then, that even the limited degree of contamination of these shellfish, which has been observed, is of some significance.

I do not think that, on the present evidence, the pollution can be regarded as so dangerous as to necessitate drastic measures. To justify interference with this particular industry, topographical and bacteriological evidence, indicating more serious pollution, would be required. It is also an insufficient statement merely to say that mussels derived from (say) the estuary of the Conway had produced enteric fever in (say) Manchester. All other possibilities of contamination between the date

of gathering from the mussel beds and that of consumption would have to be excluded. It is well known that mussels are sometimes kept by the dealers for a considerable time before being sold. Thus an enquiry into a case of ptomaine poisoning in Liverpool some years ago showed that an interval of seven days had elapsed between the dates of gathering and collection, and nine days between gathering and the death of the person consuming the mussels. In the course of a period of this duration, or even of less, the possibility of contamination of mussels, from sources other than the natural habitat of the shellfish, must be a very real one. Such extraneous contamination is all the more possible when the mussels are stocked by the lower class of dealers.

It may reasonably be urged, however, that the amount of pollution of the Conway mussels is such as to make it most desirable that some measures should be taken to reduce the contamination of the River Conway—and, consequently, of the mussels there—as far as is possible. It will be seen that seven sewers open into the river within a very limited area, and these do not represent all the contributing sources of pollution. In the construction of the existing Conway sewerage systems, as in that of many other sea-side towns, the nearest and most convenient point of discharge into tidal waters has been chosen, without much regard to the possibility of fouling either shellfish beds or foreshore. At Conway the sewage is crude, it flows continuously into the river and in some cases spreads itself over sand or mud flats, producing some contamination of these. Without venturing to express an opinion on points of sanitary engineering, I think it might be quite practicable to take steps which would do away with much of the evil effects of the present sewerage system. The Conway mussel industry is one of

great importance. This will be seen from the following statement supplied by Dr. Jenkins:—

Return of mussels landed at Conway during part of the year 1906:—

| Month. | Amount. Cwts. | Value. £ | |
|---|---|---|---|
| January ... | 2520 ... | 302½ | |
| February ... | 1948 ... | 234 | |
| March ... | 1267 ... | 137 | |
| April to August ... | — ... | — | (close season) |
| September ... | 3800 ... | 570 | |
| October ... .. | 5820 ... | 730 | |

A number of bags of mussels were lying on the beach, packed for export, on the occasion of our first visit. These were consigned to Manchester, Leeds, Huddersfield, Halifax and Nottingham.

The price obtained by the fishermen varies from 2s. to 4s. per cwt. Men and women are employed. The men usually fish from open boats by means of the long rake. The women gather the mussels from the scars by hand. I am informed that many of the women are employed by a local fisherman, who pays them 1s. 3d. per bag, for the mussels obtained.

A considerable revenue is thus yielded by the mussel beds in the Conway river, and it is not unreasonable to suggest that some public expenditure on an improved system of sewage disposal is the duty of the local authority and would be justified in its results.

It has been suggested to me by Mr. Delamotte that a portion of the river might be closed by co-operation with the Harbour Authority. It is true that the contamination is pretty general and affects not only the mussels in the river near the Bridge, but also those in the Channel below Deganwy. But the prohibition of taking mussels from the former locality would at least exclude those shellfish

which are most exposed to sewage pollution. If such action should be decided upon, marks delimiting the proposed closed area could easily be selected. By far the greater portion of the mussels sent to the markets are taken from below Deganwy, and the closing of the upper beds would not be a real hardship.

**The Conway Sewerage System.**

The positions of the principal sewers are shown on the sketch chart (reduced from one marked by Mr. Delamotte). Seven outfall sewers open into the Conway river between Llandudno Junction and the Ferry. Nos. I. and II. discharge the sewage produced in Conway itself. Nos. III. and IV. supply a small group of houses, including the Conway Union Workhouse, at Morfa, opening into a small stream which flows over a mud flat, and opens into the channel at Bodlondeb Point. On the Deganwy side there are two sewer outfalls. No. V. is situated to the North of the Pier. This outfall formerly terminated some distance above low-water mark, and, as it was producing a nuisance, Dr. Fraser recommended that the pipe should be carried further into the channel, and this has now been done. No. VI. serves Tywyn and opens on the sands some distance above low-water mark. At its extremity the sands are rather foul. No. VII. serves the neighbourhood of Llandudno Junction. It is a large and fairly important outfall, which opens into a little stream which runs over the mud flat South of the London & North Western embankment, and opens into the river immediately above the Bridge. It is carried down some distance from the shore, but terminates far above low-water mark. The stream itself is very foul, and the mud on either side of it is not much better. The mud is very soft, and immediately beneath the surface is black and

smells badly. I should compare this deposit with the sludge in a sewage purification tank—in kind only; of course it is not nearly so foul. No doubt it has become thoroughly permeated with sewage which is there undergoing putrefactive purification, with an accompanying deposition of the amorphous black substance which forms the sludge of a septic tank, and with the liberation of sulphuretted hydrogen, and perhaps marsh gas. Both sewage paper and faecal matter were very much in evidence in this stream and on its banks. Of course, this outfall and area are at some distance from the larger mussel beds, but it must contribute to the pollution of the rivers.*

In addition to these sources of contamination there must be others further up the Conway river. The sewage of some of the villages in the neighbourhood, such as Llanrwst, Glan Conway and Bettws-y-Coed, must be discharged into the upper reaches of the Conway, and no doubt contribute notably to the pollution of the latter.

The sewers I have referred to all convey crude sewage and discharge continuously into the river. It is true that tidal flap valves are fixed at their ends, but I question whether these fixtures can generally act in preventing the flow of liquid from the pipes when the latter are covered by the flood tide. In some cases the flaps were certainly choked by debris of various kinds and could not have closed. At any rate, the sewers discharge through the period of ebb tide and for a considerable part of the flood, since their outfalls are mostly well above low-water mark. It is especially near the time of low water, when the volume of the river is small, that the latter becomes

* It will be seen from the Chart that the short stream conveying this sewage into the Conway opens into the latter immediately above the bridge. Mussels are taken from just this part of the river—in fact almost opposite the mouth of the stream referred to.

polluted. For an hour before low water the sewage probably does not pass out to sea and must be carried up the river with the next flood. A considerable volume of polluted water must then simply oscillate up and down the upper reaches of the river, and some of it must pass out on every tide over the mussels at the mouth of the channel.

The population of the Borough of Conway is about 5,000. Taking the usual constant of water supply of 25 gallons per head for 24 hours, we find that 125,000 gallons of crude sewage is discharged per 24 hours—an estimate which does not include the contribution from the population further up the river.

It was suggested to us during our first visit that the sewage from Llandudno might possibly affect the Conway area. At Llandudno there are three outfall sewers which open out on the foreshore to the South of Great Orme's Head. Two of these outfalls discharge rain and surface land water, and need not be considered. The third conveys the sewage of Llandudno. It consists of two iron pipes which pass out over the sands, supported on piles, to a buoy which is at low-water mark of ordinary tides. These two pipes are connected and have a single outfall. They are shown on the Admiralty Chart (Holyhead to Liverpool —Western Sheet), but I am informed that about two years ago the lower end of the pipe became sanded up, and about 150 yards were added to the length. When I saw this outfall there were absolutely no indications of sewage matters on the foreshore as far down the length of the pipe as we could go. Automatic valves at the end of the pipe and at the penstock chamber at the beach end open and close when the tide turns, not merely when the end of the pipe is bared or covered, but when the stream changes. The sewage is thus discharged only on the ebb

tide. To accommodate the flow when the valve is closed, underground tanks, or culverts, have been constructed, which contain the sewage while the flood tide lasts. Whenever the state of the tide permits, these culverts are regularly scoured by men to prevent the accumulation of sludge. The tide, on the ebb, sets round Great Orme's Head and out to sea, and the sewage is carried in this direction. Mr. Little, Sanitary Inspector of Llandudno, informs me that this course of the sewage can actually be traced by observing the oily-looking appearance of the water as it rises to the surface. The Llandudno sewerage system appears to be remarkably well designed. Of course it might be treated, but in this case the necessity is not so strong. I do not think, therefore, that it can reach Conway Estuary unless very exceptionally, as, for instance, on the very last of the ebb and with the driving force of a strong N.W. wind. In any case, the dilution on the flowing tide would be so enormous that appreciable pollution at Deganwy could hardly occur as the result of Llandudno sewage.

The estimated population of Llandudno is about 10,500, and, taking the water supply as 25 gallons per head, the daily discharge of sewage is about 262,500 gallons. The sewage is untreated.

**Bacteriological Analyses.**

The methods followed were similar to those employed in the analyses of the Morecambe mussels, except that in the case of the Conway mussel a period of 20 hours only elapsed between the inoculation and counting of the primary plates; this because of the rapid growth of the colonies. The samples were brought back to Liverpool late at night and kept in ice for about 12 hours, when they were examined.

Two separate series of analyses were made. The results of the first (mussels and water collected about 4 p.m., 17th October, 1906), are as follows:—

### 1st Analysis.

### Primary Cultures on Neutral-Red, Bile-salt, Lactose Agar Plates.

| Locality. | Mussel. | No. of Colon-like Colonies. | White Colonies. | Enteritidis reaction. |
|---|---|---|---|---|
| Middle of | 1 | 4 | 0 | + |
| River below | 2 | 28, 1 large batch | 0 | |
| Bridge | 3 | 30, 1 long streak | 0 | — |
| | 4 | 26 | 0 | |
| Off Deganwy | 5 | 16 and general fusion | 0 | + |
| just below Pier | 6 | 73 | 5 | |
| | 7 | 15 and general fusion | 0 | + |
| | 8 | 20 and 2 long streaks | 1 streak | |
| Well below | 9 | 45, some fusions | 1 | + |
| Deganwy | 10 | 51 | 1 patch | |
| | 11 | 38 | 0 | + |
| | 12 | 15 | 0 | |
| Opposite Perch in Channel | 13 | 28 (not so typical) | 0 | + |
| | 14 | 34 | 1 patch | |
| | 15 | Numerous and fused | 0 | + |
| | 16 | 25 | 0 | |

In the case of Mussel 3, the milk tube was discoloured.

Fourteen of these colonies identified as "colon-like" were then examined further in pure subculture, with the following results:—

## Results of Tertiary Subcultures from Primary Plates.

| Mussel. | Bile-salt. | Glucose. | Lactose. | Mannose. | Cane sugar. | Milk. | Motility. |
|---|---|---|---|---|---|---|---|
| 1 | a | a | a | a | a | d | + |
| 2 | a g | a g | a g | a g | o | a c | + |
| 3 | a g | a g | a g | a g | d | a c | + |
| 4 | a g | a g | a g | a g | o | a c | + |
| 5 | a | a | a | o | a | a | — |
| 6 | a g | a g | o | a | a | d | + |
| 7 | a g | a | o | a | a | d | ?+ |
| 8 | a g | a g | a g | a g | a g | a c | — |
| 9 | a g | a g | a | a g | a | a | + |
| 9 | a g | a g | a g | a g | o | a c | + |
| 10 | a g | a g | a g | a g | a g | a c | + |
| 11 | a g | a g | a g | a g | o | a c | + |
| 11 | a g | a g | a g | a g | a | a c | + |
| 12 | a g | a g | a g | a g | a g | a c | + |

Of these colonies 1, 5, 6, 7, 8 and 9 are not those of *B. coli*. But eight give the reactions which I associate with the typical colon bacillus.

### 2ND ANALYSIS.

On this occasion only one sample of mussels was collected. The boats were working down below Deganwy and we obtained a freshly raked sample from one of them. Ten mussels were examined as before, with the following results: —

| Mussel. | No. of "colon-like" colonies. | No. of white colonies. | Enteritidis reaction. |
|---|---|---|---|
| 1 | 29, 1 large patch | 0 | + |
| 2 | 62, several patches | 0 | |
| 3 | 51, large fused patch | 0 | + |
| 4 | 22 | 17, several patches | |
| 5 | 50, 1 patch | 2 | + |
| 6 | 19, 1 patch | 1 | |
| 7 | 41, several patches | 0 | + |
| 8 | 48, some fused streaks | 0 | |
| 9 | 22, several patches | 0 | + |
| 10 | 34, several large patches | 0 | |

Subcultures of these colonies gave the following results: —

### 2ND ANALYSIS.

### RESULTS OF TERTIARY SUBCULTURES FROM PRIMARY PLATES.

| Mussel. | Bile-salt. | Glucose. | Lactose. | Mannose. | Cane sugar. | Milk. | Motility. |
|---|---|---|---|---|---|---|---|
| 1 | a g | a g | a g | a g | a g | a c | + |
| 2 | a g | a g | a g | a g | o | a c | + |
| 3 | a g | a g | a g | a g | a | a c | + |
| 4 | a | a | o | a | a | a | + |
| 5 | a | a | o | o | o | o | ? + |
| 6 | a g | a g | a g | a g | o | a c | + |
| 7 | a | a | a | a | a | a c | + |
| 8 | a g | a g | a g | a g | o | a c | + |
| 10 | a g | a g | a g | a g | a | a c | + |

The colony from mussel 4 was a typical white colony. Those from mussels 5 and 7 were "colon-like" colonies. Those from mussels 1, 2, 3, 6, 8 and 10 are typical colon bacilli. The others are not this microbe. Six colonies out of nine are therefore *Bacillus coli*. The white colonies on these and the next series of plates are being studied further.

### Sea-water Analyses.

On our first visit two samples of water were taken: one from off the Scar opposite the beach and the other from near the Bridge. These were diluted so that various solutions of different strengths were obtained, and cultures were made in neutral-red, bile-salt, lactose agar. The results are as follows:—

| | Amount of original water sample taken. | No. of colon-like colonies. |
|---|---|---|
| Off Scar, opposite Perch | 1 c.c. ... | 16 |
| | 0·1 c.c. ... | 1 |
| | 0·01 c.c. ... | 1 |
| | 0·001 c.c. ... | sterile |
| Near Bridge | 1 c.c. ... | 19 |
| | 0·1 c.c. ... | 2 |
| | 0·01 c.c. ... | sterile |
| | 0·001 c.c. ... | sterile |

On our second visit three samples of water were taken: one from below Deganwy, one from off Bodlondeb Point, and one from opposite Conway. The samples were collected in 500 cc. bottles. One cc. was taken from near the top of each bottle, and 1 cc. from the bottom layer. These were examined as before, with the following results:

| Source. | | No. of colon-like colonies in 1 cc. |
|---|---|---|
| Below Deganwy | ... | 6 |
| ,, | ... | 5 |
| Off Bodlondeb Point | ... | 31 |
| ,, ,, | ... | 23 |
| Channel, opposite Conway | ... | 77 |
| ,, ,, | ... | 63 |

Photographs of these Plates are shown in Pl. III.

These water analyses show some considerable general pollution of the river and channel. The first series was taken about low water of a spring tide and the pollution at Deganwy is noticeable. There is practically no difference in the bacteriological condition of the water at the Bridge and far down the river. This, I take it, is because of the rapid tidal stream which has thoroughly mixed up the water in the river. In the second analysis, however, we see a considerable difference in the degree of contamination of the river water. The nearer the Bridge the greater is the contamination. These samples were taken about an hour before low water on a neap tide, when the velocity of the stream in the river was not so great as on the previous occasion.

It would, of course, be desirable to carry these investigations of the pollution of the river water by sewage bacteria much further than has been possible on these occasions. But so far as they go they indicate the pollution of the river water *from above*. They also show, I think, an undesirable amount of sewage bacteria in the water of the river.

## 4.—Analysis of Mussels from Roosebeck Inner Scar.

On 28th November, 1906, Mr. A. Scott sent me a sample of mussels from Roosebeck Inner Scar, near Piel, Barrow-in-Furness. At the time of collection the scar was being fished by a few men to the extent of about 60 bags per month. It is of little importance as a source of supply for the public markets, as it is a small scar and is only occasionally fished. But its position is such as would justify one in stating that the shellfish contained on it are reasonably free from pollution. In these circumstances we thought it might be interesting to make a preliminary analysis.

Ten mussels were examined in the usual way and with all necessary precautions. The results are as follows:—

Results of Primary Cultures on Neutral-Red Agar Plates.

| Mussel. | "Colon-like" Colonies. | White Colonies. | Enteritidis reaction. |
|---|---|---|---|
| 1 ... | 20, several patches | ... 0 ... | + |
| 2 ... | 45, several patches | ... 0 ... | + |
| 3 ... | 9 | ... 0 ... | + |
| 4 ... | 9 | ... 0 ... | + |
| 5 ... | 2 | ... 0 ... | + |
| 6 ... | 24, several patches | ... 0 ... | + |
| 7 ... | 28 | ... 0 ... | + |
| 8 ... | 13 | ... 0 ... | + |
| 9 ... | 3 | ... 0 ... | + |
| 10 ... | 9 | ... 0 ... | No change. |

Ten of these "colon-like" colonies were then selected and cultivated on ordinary nutrient agar, and then tertiary sub-cultures were made. The results of these latter sub-cultures are:—

RESULTS OF TERTIARY SUB-CULTURES.

| Mussel. | Bile-salt. | Glucose. | Lactose. | Mannose. | Cane Sugar. | Milk. |
|---|---|---|---|---|---|---|
| 1 | a g | a g | a g | a g | 0 | a |
| 2 | a g | a g | a g | a g | 0 | a c |
| 3 | a g | a g | a g | a g | 0 | a c |
| 4 | a g | a g | a g | a g | 0 | a c |
| 5 | a | a | a | a | 0 | a |
| 6 | a g | a g | a g | a g | 0 | a c |
| 8 | a g | a g | a g | a g | 0 | a c |
| 9 | a g | a g | a g | a g | 0 | a c |
| 10 | a g | a g | a g | a g | 0 | a c |
| 10 | a g | a g | a g | a g | 0 | a c |

All these colonies, except Nos. 1 and 5, are, therefore, those produced by *Bacillus coli*, or by a very closely allied organism.

CONCLUSION.—The results indicate a certain degree of sewage pollution. This is, indeed, slight—so slight as to be certainly insufficient to justify any degree of interference with the local industry, unless other evidence were forthcoming which might render these bacteriological results of significance. Now it is here that one might expect freedom from sewage contamination. There are only two neighbouring towns, Barrow and Ulverston, the influence of which need be considered, and the situation of these places with respect to Roosebeck Scars is not such as to lead us to expect serious pollution of the latter, especially when the direction of the tidal streams is considered. Nevertheless, sewage bacteria are carried to the mussels. I can only suggest that the sea all along the coast of Lancashire is generally slightly polluted with sewage matters, and that it is this general pollution of the sea water which is the cause of the contamination in cases like the present one.

To what extent does the sea contain sewage bacteria?

Investigations have not, so far, been made in the Irish Sea, and we have thus no means of ascertaining how far the pollution in any specific case is due to this supposed general contamination. It is because one is unable precisely to separate the effects of this general (and probably harmless) contamination from local and always potentially dangerous pollution that there must frequently be difficulty in interpreting such results as this analysis gives. A thorough examination of the distribution of colon bacilli in the coastal waters of Lancashire would undoubtedly be of practical value.

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Explanation of Plate and Charts.

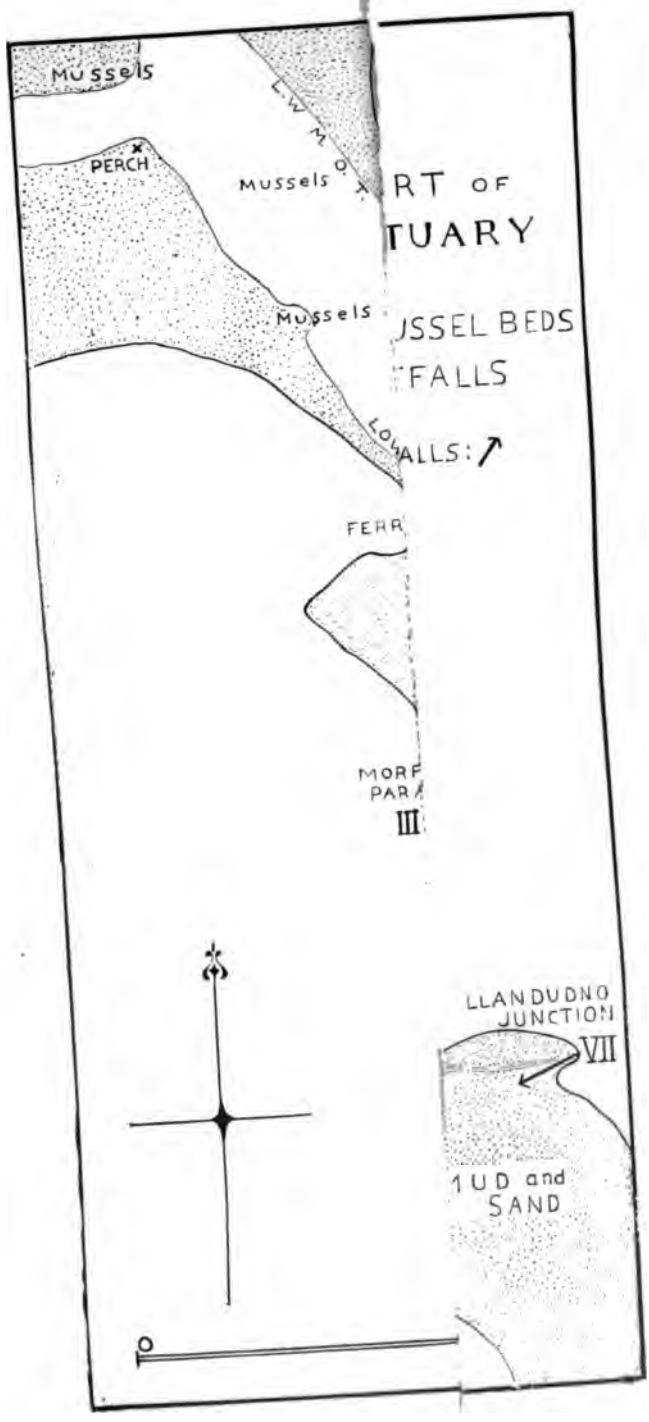
Chart V.—Chart of the sea near Morecambe, shewing mussel beds and sewers.

Chart VI—Similar chart of the Conway Estuary.

Plate X.—Three cultures made by inoculating 1 c.c. of river water in neutral red, bile-salt lactose agar. Photograph by A. Scott, slightly reduced.

ER SANDS
RIVER KEER
Stone Skear
Little Skears
Baiting Knott
4 Reap Skear 2
RING HOLE
IV V
CENTRAL PIER
III
OLD HARBOUR
II
Ring Sand
MORECAMBE
WEST END PIER
I
GROSVENOR HOTEL
SEWER OUTFALLS.
I. MAIN OUTFALL -TREATED SEWAGE.
II-VI. CRUDE SEWAGE OUTFALLS.
CHART
SHOWING THE POSITIONS
OF THE
MUSSEL BEDS OR SKEARS
AND SEWER OUTFALLS.
AT
MORECAMBE.
MUSSEL BEDS:
BAULKS:
SEWER OUTFALLS.
LES 0 MILE 1

CHART VI.


MUSSELS
PERCH
MUSSELS
MUSSELS
RT OF
TUARY
JSSEL BEDS
FALLS
ALLS:
FERR
MORF
PAR
III
LLANDUDNO
JUNCTION
VII
1UD and
SAND
0

## Plate X.

Conway River: 1 cc. water from below Deganwy.

Conway River: 1 cc. water from off Bodlondeb Point.

Conway River: 1 cc. water from opposite Conway.

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A3

No. XVI.

# REPORT FOR 1907,

ON THE

# LANCASHIRE SEA-FISHERIES LABORATO

AT

THE UNIVERSITY OF LIVERPOOL,

AND THE

# SEA-FISH HATCHERY AT PIE

DRAWN UP BY

Professor W. A. Herdman, D.Sc., F.R.S.,

*Hon. Director of the Scientific Work,*

Assisted by Mr. Andrew Scott, A.L.S., and

Mr. James Johnstone, B.Sc.

*WITH ILLUSTRATIONS.*

LIVERPOOL:

Printed by C. Tinling and Co., Ltd., 53, Victoria Street

1908.

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# REPORT on the INVESTIGATIONS carried on during 1907 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With plates and text figures.)

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## INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

On account of my mission to the Ceylon pearl banks in February and March, this Report does not appear this year until a few weeks later than the usual date. There are, however, advantages in the slight delay, since it has enabled one or two of the sections to be more thoroughly worked up. Moreover, as this report deals with the completed work up to the end of 1907, it really, in going to press in April, is appearing in very good time compared with the usual practice of most Annual Reports.

## Work at Piel.

There is comparatively little that need be said about the work at the Piel laboratory and hatchery. Mr. Scott's section of the report (see below) will show that he has successfully hatched and turned out into the sea about thirteen and a half millions of young flat fish. He reports to me that the spawning fish he now has are in satisfactory condition and that the prospects for the present season are good.

The fishermen's classes were held at the Piel Laboratory in the usual manner and with the usual success. One of the results of the continued success of these classes, and of our natural desire to hold as many of them as is possible in the season, is that our two scientific assistants, Mr. Johnstone and Mr. Scott, are occupied in this work during that period of the year when the principal food-fishes are spawning, when the eggs are appearing in our surface nets and other changes are taking place in the floating life of the sea. I feel that it is a distinct loss to us that these naturalists are prevented at that important part of the year from taking almost daily observations from the steamer. When we get, as I hope we soon shall, an increase in our investigating staff it will be very important to have one naturalist at least on the steamer constantly, engaged in carrying on investigations and in recording observations daily.

Mr. Scott contributes a section of this report on the results of the Hensen net hauls undertaken in the eastern portion of the Irish Sea between Barrow and North Wales. These results are interesting not only for comparison amongst themselves, station with station and period with period throughout the year, but also because

of the considerable differences that they present to the hauls made with the Hensen, Nansen and other forms of net off Port Erin and elsewhere round the South end of the Isle of Man.

As Mr. Scott points out, we have during this last year collected and examined more than twice as many gatherings as in any previous year. The Plankton discussed in last year's report amounted to 400 samples; this year it has run up to nearly 900. The increase is, however, due not so much to work in the Lancashire district as to the very large number of samples which I took with various kinds of experimental nets from the S.Y. "Ladybird" during the spring, summer and autumn of the past year. The results of these experimental hauls are recorded on 126 sheets, many containing records of from five to ten hauls each. The total number of hauls by means of which we have sampled in this manner the water round the South end of the Isle of Man amounts to about 650. This large series has enabled Mr. Scott and myself to discuss the succession of organisms in the Plankton throughout the year in a limited area, and also the distribution, and relative numbers at different times and places, in a manner which had not been previously possible to us. This is only the beginning of such an intensive study of small areas as will be necessary before we can arrive at any correct estimate of the value and representative nature of such samples.

Mr. Buchanan-Wollaston, who has been carrying on fishery work in the University Laboratories, under a grant from the Board of Agriculture and Fisheries, contributes a couple of short papers to this report as the result of his examination of the statistics we have accumulated during the last fifteen years. Although these statistics seem, at first sight, to be large in quantity,

on examination it is found that so many gaps occur in the series that they are not so complete and not so valuable for scientific purposes as might have been expected. It is very unfortunate when a series of observations is deprived of much of its value through some monthly observations having been omitted on account of the steamer being called off to other duties. Every endeavour ought to be made, now that we are starting work with a new, more powerful and more scientifically-equipped vessel, to carry out the periodic observations with punctuality in order that the statistics acquired may be of the greatest possible value—not merely for our own immediate purposes but also for the benefit of future fishery administrators.

Dr. H. Bassett, of our University Chemical Department, has most kindly for the last couple of years undertaken the physico-chemical work in connection with the examination of the samples of sea water obtained on the periodic hydrographic cruises, and he now contributes to this report a paper on his results which is of very great interest; and shows that this work ought certainly to be continued and extended.

Mr. Johnstone has been engaged during the year in his usual important work on the bacteriological examination of the shell-fish beds of the district, but is not yet prepared to report further on the matter. He has also been engaged in working up the results of the marked fish experiments, and has continued to devote attention to the parasites of fishes in the district, and we have from him in this report articles on these two latter questions, to which I need not allude further.

I have pleasure in appending to the report this year a comprehensive memoir on *Cancer*—the Edible Crab, written by Mr. Joseph Pearson, M.Sc. of the Zoological

Department of the University. Mr. Pearson has been working on this Memoir for several years, part of the expenses of his material being met by a grant from the Board of Agriculture and Fisheries, and part of the expense of producing the beautiful plates which illustrate the structure and life-history of the Crab being met by a grant from the fund for research, placed at the disposal of the University by H.M. Treasury, while the remainder of the cost of the plates will be defrayed by the Liverpool Marine Biology Committee. Mr. Pearson has discussed his subject from practically every point of view and has produced an account of the Crab which will, I hope, be regarded as the authoritative work on this important food-animal, and will, I am sure, be a credit to our report and to the Sea Fisheries Committee under whose auspices it is produced.

W. A. Herdman.

Fisheries Laboratory,
University of Liverpool,
*February* 5, 1908.

## SEA-FISH HATCHING AT PIEL.

By Andrew Scott.

The results of the hatching work in the spring of 1907 are very similar to those obtained in the previous year. The adult plaice were brought from Luce Bay by the Fisheries steamer and the flounders from the Barrow Channel by the cutter belonging to the northern division of the district.

The plaice and flounders commenced to spawn on March 2nd, and the first fertilised eggs were secured two days later. The spawning period lasted for two months, and during that period one million four hundred thousand plaice eggs were collected and thirteen million eight hundred thousand flounder eggs. The eggs were incubated in the usual way in the Dannevig apparatus and the resulting fry liberated in the sea. The parent fish were afterwards set free in the Barrow Channel. Towards the end of the year the local fishermen again reported the capture of unusually large plaice from the channel. It is proposed during the present year to find out whether the adult plaice liberated at the end of the hatching season remain in the channel and are eventually captured or entirely leave the neighbourhood. Before being set free a number of the stronger plaice will be marked with the brass label and button as in an ordinary migration investigation, and no doubt the local fishermen will be glad to assist by returning any marked fish that they capture.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified:—

PLAICE (*Pleuronectes platessa*, Linn.).

| Eggs Collected. | | | Fry Set Free. | | |
|---|---|---|---|---|---|
| March 4 | ... | 12,000 | 10,000 | ... | March 30 |
| ,, 6 | ... | 20,000 | 17,500 | ... | ,, ,, |
| ,, 8 | .. | 20,000 | 17,500 | ... | April 6 |
| ,, 11 | ... | 40,000 | 35,000 | ... | ,, ,, |
| ,, 14 | ... | 45,000 | 40,000 | ... | ,, 13 |
| ,, 18 | ... | 65,000 | 57,500 | ... | ,, ,, |
| ,, 20 | ... | 65,000 | 57,500 | ... | ,, 20 |
| ,, 22 | ... | 75,000 | 65,500 | ... | ,, ,, |
| ,, 26 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 29 | ... | 90,000 | 79,500 | ... | ,, 27 |
| April 1 | ... | 95,000 | 84,500 | ... | ,, ,, |
| ,, 3 | ... | 95,000 | 84,500 | ... | ,, ,, |
| ,, 5 | ... | 95,000 | 84,500 | ... | May 4 |
| ,, 8 | ... | 90,000 | 79,500 | ... | ,, ,, |
| ,, 11 | ... | 85,000 | 75,000 | ... | ,, 11 |
| ,, 15 | ... | 85,000 | 75,000 | ... | ,, ,, |
| ,, 17 | ... | 80,000 | 70,000 | ... | ,, ,, |
| ,, 19 | ... | 70,000 | 62,000 | ... | ,, 18 |
| ,, 22 | ... | 60,000 | 52,500 | ... | ,, ,, |
| ,, 24 | ... | 50,000 | 40,000 | ... | ,, ,, |
| ,, 26 | ... | 30,000 | 26,500 | ... | ,, 22 |
| ,, 29 | ... | 25,000 | 22,000 | ... | ,, ,, |
| May 1 | ... | 18,000 | 15,500 | ... | ,, ,, |
| Total Eggs | | 1,400,000 | 1,231,000 | | Total Fry. |

## Flounder (*Pleuronectes flesus*, Linn.).

| Eggs Collected. | | | Fry Set Free. | | |
|---|---|---|---|---|---|
| March | 4 | 150,000 | 133,000 | March | 30 |
| ,, | 6 | 200,000 | 177,000 | ,, | ,, |
| ,, | 8 | 300,000 | 266,000 | ,, | ,, |
| ,, | 12 | 400,000 | 355,500 | April | 6 |
| ,, | 14 | 600,000 | 532,000 | ,, | ,, |
| ,, | 18 | 600,000 | 532,000 | ,, | ,, |
| ,, | 20 | 700,000 | 622,000 | ,, | 13 |
| ,, | 22 | 800,000 | 712,000 | ,, | ,, |
| ,, | 26 | 800,000 | 712,000 | ,, | ,, |
| ,, | 29 | 950,000 | 846,500 | ,, | 20 |
| April | 1 | 1,000,000 | 887,000 | ,, | ,, |
| ,, | 3 | 1,000,000 | 887,000 | ,, | ,, |
| ,, | 5 | 900,000 | 800,000 | ,, | 27 |
| ,, | 8 | 800,000 | 712,000 | ,, | ,, |
| ,, | 11 | 800,000 | 712,000 | May | 4 |
| ,, | 15 | 800,000 | 712,000 | ,, | ,, |
| ,, | 17 | 600,000 | 532,000 | ,, | ,, |
| ,, | 19 | 600,000 | 532,000 | ,, | 11 |
| ,, | 22 | 500,000 | 445,000 | ,, | ,, |
| ,, | 24 | 500,000 | 445,000 | ,, | ,, |
| ,, | 26 | 200,000 | 177,500 | ,, | 18 |
| ,, | 29 | 200,000 | 177,500 | ,, | ,, |
| May | 1 | 150,000 | 133,000 | ,, | 22 |
| ,, | 3 | 150,000 | 133,000 | ,, | ,, |
| ,, | 5 | 100,000 | 89,000 | ,, | ,, |
| Total Eggs | | 13,800,000 | 12,262,000 | Total Fry. | |

Total Number of Eggs ... ... ... 15,200,000

Total Number of Fry ... ... ... 13,493,000

## CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

Following the system that has now been in operation for several years, the Education Committee of the Lancashire County Council renewed the grant which enabled forty-five bona-fide fishermen residing in the Administrative County of Lancaster to attend a course of instruction at Piel in 1907. The Blackpool Education Committee again sent three men, and the Cheshire Education Committee six men from Hoylake. The studentship holders were divided into four classes, three of fifteen each and one of nine men, as shown by the following lists:—

First Class, held February 25th to March 9th.—John Randles, Hoylake; Sydney Beck, Hoylake; Thomas Nicholson, Hoylake; J. Bird, Hoylake; William Smith, Hoylake; R. Jones, Hoylake; Daniel Cross, Askam-in-Furness; A. Woodhouse, Morecambe; M. Woodhouse, Morecambe; R. Baxter, Morecambe; N. Sumner, Fleetwood; W. Cartmell, Fleetwood; R. Gornall, Fleetwood; H. Johnson, Banks; T. Leadbetter, Banks.

Second Class, held March 11th to 22nd.—G. Thompson, Roosebeck; T. Stephenson, Flookburgh; H. Townley, Morecambe; J. Raby, Morecambe; A. Woodhouse, Morecambe; S. Butler, Fleetwood; J. Abram, Fleetwood; W. Leadbetter, Fleetwood; W. Wade, Fleetwood; W. Hardman, Lytham; A. Anderson, Lytham; E. Rimmer, St. Annes; W. Harrison, St. Annes; Stephen Johnson, Banks; A. Abram, Banks.

Third Class, held April 8th to 19th.—Edward Martin, Baycliff; Thomas Thompson, Baycliff; Albert Hill, Flookburgh; William Benson, Flookburgh; Albert Threlfall, Morecambe; John Houghton, Morecambe;

John Woodhouse, Morecambe; Robert Bell, Morecambe; James Butler, Glasson Dock; John Hardie, Fleetwood; James McMillan, Fleetwood; Joseph Price, Fleetwood; Ernest Railton, Fleetwood; John Abram, Banks; Geoffrey Wareing, Banks.

Fourth Class, held April 22nd to May 3rd.—David Rawlinson, Roosebeck; James Burrow, Bolton-le-Sands; W. Lawrence Fawcett, Morecambe; John Burrow, jun., Heysham; William Hargreaves, Knott End, Fleetwood; John Bridge, Banks; Thomas Melling, Blackpool; Ezekiel Salthouse, Blackpool; Henry Smith, Blackpool.

The usual votes of thanks to the Sea Fisheries Committee and to the Education Committee were proposed and carried by the fishermen.

Two classes in nature study for school teachers were held during the months of April and May. The classes were organised by the Barrow Education Committee and were attended by teachers belonging to their schools. The course of instruction for school teachers has, on the suggestion of Mr. A. Haveridge, Director of Education at Barrow, been somewhat modified and re-arranged. The course has been divided into three stages. The first deals with the common organisms of the sea shore between tide marks, and the general animal and plant remains from the sea bottom washed up along high-water mark. A brief account of their distribution, habits, and uses is given, and an explanation of the methods of collecting, preserving, and mounting natural history specimens for school museums. In the second stage certain common types of marine animals are studied more fully than in the first course. These types include a common fish like the codling or herring, starfishes and sea urchins, common shore crabs, cockle, mussel, &c. The third stage deals with microscopical preparations, the use of the tow-net,

microscopic life in the sea, and the life-history of some common type of marine animal.

A large party, consisting of representatives of the Sea Fisheries Committee and the various Educational Committees of Lancashire, visited the laboratory on April 24th and saw the fishermen at work. An interesting address on the scientific and educational work of the Sea Fisheries Committee as applied to fishermen was given by Mr. A. T. Wright, and was greatly appreciated by the audience. Mr. Walter E. Archer, Assistant Secretary to the Department of Agriculture and Fisheries, inspected the establishment in April. Mr. M. A. Fenton, one of H.M. Inspectors of Schools, visited the laboratory to inspect and report on the work of the classes for fishermen and school teachers

A good deal of time has been devoted to the examination of the pelagic organisms in the Irish Sea around the Isle of Man, and from there to Lancashire and to Cardigan Bay, which were collected by various kinds of nets at depths ranging between the surface and 60-70 fathoms. In fact, 1907 makes a record for this part of our work. In 1906 the number of plankton samples collected and examined was just four hundred, while in 1907 that total was fully doubled, as is shown by the following figures:—

| | |
|---|---|
| Ordinary tow-net collections by the Fisheries steamer ... ... ... | 160 |
| Hensen Net, monthly observations ... | 27 |
| Fishery officers in Cardigan Bay, ordinary tow-net ... ... ... | 60 |
| Samples taken by various nets around the Isle of Man by Professor Herdman, and in Port Erin Bay by Mr. Chadwick and others ... ... ... | 638 |
| Collections made round the West of Scotland by Professor Herdman ... | 10 |
| Total... ... ... | 895 |

Owing to the necessary arrangements in contemplation of the sale of the former Fisheries steamer and the delay in delivery of the "James Fletcher," Captain Wignall's collections could not be so systematically made as in former years, and the number is naturally reduced in consequence. The results of the monthly observations with the Hensen net and of the extensive series of collections taken by Professor Herdman from the S.Y. "Ladybird," are dealt with elsewhere in this report. The other collections are in process of being worked up, and reports upon them will be given later.

# MONTHLY INVESTIGATION OF THE PLANKTON BY THE HENSEN NET METHOD.

By Andrew Scott.

This investigation was commenced in January, 1907, with the intention that regular hauls should be taken at intervals of one month, between Piel Gas Buoy, at the outside entrance to the Barrow Channel, and Great Ormes Head, on the North Wales coast. Owing to unforeseen circumstances the continuity of the observations was interrupted on three occasions: no hauls were taken in April, July and December. In the absence of a complete series of monthly observations it would be unwise in the present report to discuss the changes that take place, from month to month, in the pelagic organisms along the line of observation. At the same time, one or two interesting facts can be detected by a review of the tables of results given below, which are worth some attention.

Three stations have been laid down along an imaginary straight line, joining Piel Gas Buoy to Great Ormes Head. The first station is four and a half miles, the second twenty-two and a half, and the third forty and a half miles from Piel Gas Buoy. The third station is four and a half miles off the Orme's Head, and the middle station is eighteen miles equidistant from the first and third. At each station the ship is stopped, and when all way is off her the net is put over the side, lowered down to a depth of ten fathoms and then slowly drawn to the surface. The time taken to draw the net up through ten

fathoms is about sixty-five seconds. The net is then got on board and the ship continues her course to the next station. As soon as the net comes on board, the contents of the metal bucket, provided with a tap at the end of it, are run off through a fine silk filter of the same texture as the net. The tap is then shut and the outside of the net well washed down with the ship's hosepipe. In this washing of the net, the bucket is again filled with the water that passes *through* the silk, and any organism adhering to the inside of the net after the first straining are taken into the bucket with the washings. The contents of the bucket are again passed through the silk filter and the whole catch and silk of the filter are at once transferred to 3 per cent. formalin in sea water and labelled. The samples are afterwards carefully examined ashore. For an explanation of the methods now adopted in the investigation of our plankton samples, see the joint report on the plankton taken off the Isle of Man by Professor Herdman and myself.

The first point to be noted, is that the amount of life in the sea during the early months of the year is very small, from May on to September there is a great increase in bulk, and then towards the end of the year it falls away. The nine hauls taken in the first quarter of the year gave nineteen cubic centimetres of organisms, while the three hauls taken in September caught eighty cubic centimetres altogether.

Next, taking the organisms in order, we find that in January, Diatoms were scarce and only represented by two species. In February a considerable increase in numbers was found and thirteen species were present along our line of observation. A further increase was found in March and twenty species were noted. Diatoms further increased in May and the species represented reached a

total of twenty-six. In June, although the species present had fallen to nineteen, the number noted was high, and the bulk of the plant life consisted of *Eucampia* and *Rhizosolenia*. In August and September the Diatoms continued to be very abundant and the species represented were nearly as numerous as in May. In October there was a marked decrease in numbers and the species had fallen to twenty. An apparent recovery was found to have taken place in November, and the number of Diatoms taken in the three hauls was fully twice that found in the three hauls for October. During October and November there were more Diatoms in the vicinity of Walney than at the other two stations, and the central region contained the least. It will be noted that the hauls taken in October yielded $3\frac{1}{2}$, 17 and 5 cubic centimetres of organisms respectively, yet the numbers of Diatoms were completely inverted, as the following figures show: ($3\frac{1}{2}$) 24·300; (17) 7·450; (5) 12·700.

Species of *Ceratium* were present in eight out of the nine monthly hauls. They appeared to be entirely absent in the whole area in January and at Station I in February. It will be noticed from the tables that from the month of June to the end of the series, these organisms were more abundant at Station I than at either the second or third. It is evident that there is a distinct maximum period in August. Specimens of *Peridinium* were much scarcer than those of *Ceratium*, and apparently reached their maximum point a little earlier in the year.

*Noctiluca* has been recorded in our reports for some years as occurring in large numbers along the North Wales and Lancashire coasts during the summer and autumn months.

The specimens found in the hauls for January, February and March were probably survivors from the

summer of 1906, as none were observed in May. The organism was present at all the stations in June, and in large numbers again in August and September. The hauls taken in October showed a decided decrease, which became still more marked in November. It is probable that the maximum point of the invasion was reached about the end of August. The bulk of the samples taken in August and September consisted of *Noctiluca*.

Specimens of *Sagitta* were present in the area in each of the months that collections were taken, and only once appeared to be absent from any of the three stations. The largest number of specimens were taken in September. Copepoda apparently follow pretty much the same increase as the other groups, and the largest numbers were found in the September hauls.

When a complete series of hauls with the Hensen net along this line is available for comparison, it will be possible to discuss more fully the changes that take place from month to month amongst the organisms that make their appearance in the upper layers of the sea throughout the year.

Station and Date.—Hensen Net Stations, January 8th and February 5th, 1907.

| in fathoms | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 |
|---|---|---|---|---|---|---|
| in c.cm. | 2 | 3 | 2 | 2 | 3 | 2 |
| as | I. | II. | III. | I. | II. | III. |
| onella bleakeleyi | — | — | — | — | — | 25 |
| lphia mobiliensis | — | — | 8 | 800 | 570 | 800 |
| ceros decipiens | — | — | — | 600 | 200 | 100 |
| odiscus concinnus | 25 | 6 | 58 | 500 | 500 | 550 |
| granii | — | — | — | 24 | 20 | — |
| im brightwellii | — | — | — | 30 | — | — |
| ra borreri | — | — | — | 8 | — | — |
| olenia semispina | — | — | — | 30 | 30 | 100 |
| setigera | — | — | — | 20 | 10 | — |
| shrubsolei | — | — | — | — | — | 25 |
| ria paradoxa | — | — | — | 12 | — | 100 |
| chea malleus | — | — | — | 15 | 3 | — |
| hia closterium | — | — | — | — | 10 | 75 |
| scia sp. | — | — | — | — | — | 25 |
| im furca | — | — | — | — | 10 | 50 |
| fusus | — | — | — | — | 20 | 100 |
| tripos | — | — | — | — | 200 | 50 |
| ica miliaris | 1 | 30 | 100 | 14 | 10 | — |
| brachia pileus | — | — | — | — | — | 1 |
| bipunctata | 8 | 12 | 56 | 5 | 37 | 8 |
| Polychæta | 1 | — | 3 | — | — | — |
| ria' | — | — | 1 | — | 30 | — |
| stage of Crangon | 3 | — | — | — | — | — |
| iscus calani | — | — | 4 | — | — | — |
| s helgolandicus | 1 | 1 | — | — | — | — |
| calanus elongatus | 72 | 30 | 135 | 54 | 3 | 36 |
| a longicornis | — | — | — | — | 2 | 3 |
| pages hamatus | — | — | 7 | — | — | 4 |
| a clausi | 6 | 5 | 18 | 23 | 20 | 13 |
| a similis | 3 | 1 | 5 | 94 | 70 | 90 |
| lanus parvus | 35 | 16 | 119 | 52 | 25 | 15 |
| sonula hyæna | — | — | — | 3 | — | — |
| d nauplii | — | — | — | 60 | 1,290 | 150 |
| libranchs, larval | — | — | 1 | — | — | — |
| eura sp. | 1 | — | — | — | — | — |
| an eggs | 1 | — | — | — | — | — |

Station and Date.—Hensen Net Stations, March 5th, 1907.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Depth in fathoms** | 10-0 | 10-0 | 10-0 | — | — | — |
| **Catch in c.cm.** | 2 | 1½ | 1½ | — | — | — |
| **Station** | I. | II. | III. | — | — | — |
| **Asterionella bleakeleyi** | — | 25 | 50 | — | — | — |
| **Biddulphia mobiliensis** | 500 | 3,200 | 3,500 | — | — | — |
| **Chætoceros contortum** | 50 | 75 | 75 | — | — | — |
| ,, decipiens | 300 | 175 | 255 | — | — | — |
| ,, sociale | — | 50 | 25 | — | — | — |
| ,, teres | 100 | 100 | 150 | — | — | — |
| ,, subtile | 75 | — | — | — | — | — |
| **Coscinodiscus concinnus** | 900 | 630 | 625 | — | — | — |
| ,, granii | 50 | 25 | 50 | — | — | — |
| Ditylium brightwellii | 150 | 50 | 25 | — | — | — |
| Eucampia zodiacus | 25 | — | — | — | — | — |
| Rhizosolenia setigera | — | 100 | 200 | — | — | — |
| ,, shrubsolei | — | 25 | 75 | — | — | — |
| Actinoptychus splendens | 50 | — | — | — | — | — |
| Biddulphia aurita | 800 | 300 | — | — | — | — |
| ,, favus | 400 | 75 | 100 | — | — | — |
| ,, granulosa | — | 400 | 320 | — | — | — |
| **Coscinodiscus radiatus** | 875 | 1,500 | 1,600 | — | — | — |
| **Leptocylindrus danicus** | — | 25 | — | — | — | — |
| **Bacillaria paradoxa** | — | 25 | 125 | — | — | — |
| **Ceratium furca** | 25 | — | — | — | — | — |
| ,, fusus | 300 | 400 | 470 | — | — | — |
| ,, tripos | 550 | 1,000 | 420 | — | — | — |
| Peridinium sp. | — | 25 | 25 | — | — | — |
| Noctiluca miliaris | — | 25 | — | — | — | — |
| Pleurobrachia pileus | — | — | 1 | — | — | — |
| Medusoid gonophores | — | — | 1 | — | — | — |
| Sagitta bipunctata | — | 5 | 8 | — | — | — |
| Larval Polychæta | 2 | 50 | 25 | — | — | — |
| 'Mitraria' | — | 25 | — | — | — | — |
| Podon intermedium | 1 | — | — | — | — | — |
| Pseudocalanus elongatus | 42 | 20 | 25 | — | — | — |
| Temora longicornis | 1 | — | — | — | — | — |
| Centropages hamatus | 1 | — | — | — | — | — |
| Acartia clausi | 20 | 3 | 1 | — | — | — |
| Oithona similis | 3 | — | 75 | — | — | — |
| Paracalanus parvus | 3 | 1 | 2 | — | — | — |
| Cyclopina littoralis | 75 | — | — | — | — | — |
| Copepod nauplii | 775 | 1,500 | 1,200 | — | — | — |
| ,, metanauplii | 1 | — | — | — | — | — |
| ,, juv. | 100 | 50 | 175 | — | — | — |
| Barnacle nauplii | 10 | — | — | — | — | — |
| Lamellibranchs, larval | — | 75 | 125 | — | — | — |
| Oikopleura sp. | 1 | — | — | — | — | — |

## Station and Date.—Henson Net Stations, May 10 and June 5, 1907.

| Depth in fathoms | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 |
|---|---|---|---|---|---|---|
| Catch in c.cm. | 4½ | 4 | 14 | 5½ | 14 | 32 |
| Stations | I. | II. | III. | I. | II. | III. |
| Asterionella bleakeleyi | — | — | 25,000 | — | — | — |
| ,, japonica | — | — | 3,750 | — | — | — |
| Biddulphia mobiliensis | 30,000 | 43,500 | 1,190,000 | 875 | 125 | 65,000 |
| Chætoceros contortum | 125 | — | 2,500 | — | — | — |
| ,, debile | — | 1,500 | 31,000 | — | — | — |
| ,, decipiens | — | 20,000 | 81,000 | 3,700 | 75 | 50,000 |
| ,, densum | — | — | — | 1,000 | — | 500 |
| ,, sociale | 5,000 | 24,000 | 43,700 | 1,000 | — | 500 |
| ,, teres | 1,300 | 7,500 | 100,000 | 8,700 | 15,000 | 1,500 |
| ,, subtile | 875 | — | — | 16,000 | 15,000 | — |
| ,, diversum | — | 1,000 | — | — | — | — |
| Coscinodiscus concinnus | 28,000 | 20,000 | 213,000 | 625 | 2,125 | 500 |
| ,, granii | 120 | 100 | — | — | — | — |
| Coscinosira polychorda | — | — | 5,000 | 1,000 | — | — |
| Ditylium brightwellii | 1,250 | 500 | 25,000 | — | — | — |
| Eucampia zodiacus | 2,250 | 5,000 | 87,500 | 43,750 | 4,000,000 | 73,000 |
| Melosira borreri | 3,700 | 1,500 | 1,250 | 25,000 | 100,000 | 2,000 |
| Rhizosolenia semispina | 87,00 | 167,000 | 22,500 | 2,000,000 | 2,000,000 | 85,000 |
| ,, setigera | 22,000 | 12,000 | 37,000 | 6,250 | 2,500 | — |
| ,, shrubsolei | 12,000 | 3,500 | 50,000 | 63,000 | 650,000 | 70,000 |
| ,, stolterfothii | — | — | — | — | 10,000 | 1,000 |
| Biddulphia aurita | 500 | — | — | — | 2,500 | — |
| ,, granulosa | 1,250 | 500 | 1,250 | — | — | 500 |
| Coscinodiscus radiatus | 15,000 | 11,500 | 37,500 | 1,230 | 3,500 | 875 |
| Bacillaria paradoxa | — | — | 1,250 | — | — | — |
| Guinardia flaccida | 130 | 500 | 2,500 | 2,500 | 63,000 | 9,000 |
| Lauderia borealis | 500 | 500 | 12,500 | — | 2,500 | 1,500 |
| Streptotheca thamensis | — | — | 2,500 | — | — | — |
| Ceratium furca | 120 | 100 | — | 2,500 | 1,000 | — |
| ,, fusus | 5,000 | 5,500 | 7,500 | 13,750 | 2,500 | 3,000 |
| ,, tripos | 1,600 | 2,000 | 2,500 | 13,750 | 7,500 | 1,000 |
| Peridinium sp. | 2 | 500 | — | 23,500 | 6,250 | 1,500 |
| Trochiscia sp. | 875 | 1,000 | 2,500 | 2,500 | 2,500 | 3,500 |
| Noctiluca miliaris | — | — | — | 1,250 | 2,000 | 2,500 |
| Pleurobrachia pileus | — | — | — | 3 | 7 | 6 |
| Medusoid gonophores | 3 | 12 | 6 | 6 | 70 | 110 |
| Plutei of Echinoderms | — | — | — | — | 125 | — |
| Sagitta bipunctata | 3 | 4 | 7 | 23 | 31 | 30 |
| Larval Polychæta | 670 | 1,000 | 545 | 440 | 155 | 80 |
| 'Mitraria' | 250 | 100 | — | — | — | — |
| Crab zoea | 3 | 1 | 3 | 10 | 8 | 3 |
| Mysis stage of Crangon | 3 | 2 | 5 | 1 | — | 6 |
| Second stage Nephrops | — | — | — | — | — | 1 |
| Podon intermedium | — | — | — | 40 | — | — |
| Evadne nordmanni | — | — | — | 20 | 1 | — |
| Calanus helgolandicus | 1 | — | — | — | — | — |
| Pseudocalanus elongatus | 10 | 65 | 25 | 180 | 170 | 60 |
| Temora longicornis | 120 | 75 | 115 | 450 | 1,250 | 1,780 |
| Centropages hamatus | 25 | 120 | 30 | 30 | 250 | 1,200 |
| Acartia clausi | 75 | 5 | 10 | 300 | 200 | 30 |
| Oithona similis | 125 | — | — | 10 | — | 250 |
| Paracalanus parvus | — | 5 | 5 | 10 | 20 | — |
| Isias clavipes | — | — | — | — | — | 100 |
| Copepod nauplii | 13,250 | 700 | 9,000 | 11,250 | 11,250 | 500 |
| ,, juv. | 625 | 500 | 1,300 | 2,500 | 3,750 | 6,000 |
| Barnacle nauplii | 38 | 5 | 70 | 25 | 20 | 20 |
| ,, cypris stage | — | — | 3 | — | 2 | 6 |
| Gasteropods, larval | 125 | 125 | — | 375 | 375 | — |
| Lamellibranchs, larval | 250 | 250 | 1,250 | 3,750 | — | 500 |
| Oikopleura sp. | 120 | 4 | 2 | 1,150 | 1,300 | 1,350 |
| Ascidian eggs | — | — | — | 250 | — | — |
| Grey Gurnard eggs | — | — | 2 | — | 1 | |
| Solenette eggs | — | — | — | — | 1 | — |
| Post larval Plaice | — | 2 | — | — | — | — |
| ,, ,, Liparis | — | — | — | 1 | — | — |
| ,, ,, *sp.* | — | — | — | — | 1 | — |
| ,, ,, *sp.* | — | — | — | — | 2 | — |

## Station and Date.—Hensen Net Stations, Aug. 29 and Sept. 18, 1907.

| | | | | | | |
|---|---|---|---|---|---|---|
| Net used | — | — | — | — | — | — |
| Depth in fathoms | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 |
| Catch in c.cm. | 11½ | 40 | 13 | 26 | 28 | 28 |
| Station | I. | II. | III. | I. | II. | III. |
| Asterionella bleakeleyi | — | — | 750 | — | — | 500 |
| Biddulphia mobilensis | 18,000 | — | 31,000 | — | — | 1,000 |
| ,, aurita | — | — | 1,000 | — | — | — |
| Chætoceros contortum | — | — | — | 12,500 | 500 | — |
| ,, debile | 2,000 | 750 | — | 5,000 | — | — |
| ,, decipiens | 5,000 | — | 1,500 | — | 500 | — |
| ,, sociale | — | 1,000 | 2,250 | 325,000 | 170,000 | — |
| ,, teres | 1,000 | 1,000 | 7,500 | 75,000 | 3,000 | — |
| ,, densum | 110,000 | 185,000 | 63,750 | 150,000 | 3,000 | 500 |
| ,, boreale | — | — | 6,750 | 7,500 | 2,500 | |
| ,, subtile | — | — | — | 2,500 | — | — |
| Coscinodiscus concinnus | 6,000 | 5,000 | 250 | 35,000 | 4,700 | 1,000 |
| Ditylium brightwellii | — | — | 1,500 | — | — | — |
| Eucampia zodiacus | 500 | 5,000 | — | — | 70,000 | 1,000 |
| Leptocylindrus danicus | 1,000 | 150,000 | 750 | 10,000 | 2,000 | — |
| Melosira borreri | — | — | — | 5,000 | 500 | — |
| Lauderia borealis | — | — | — | 5,000 | 500 | — |
| Rhizosolenia semispina | 71,000 | — | 173,000 | 250,000 | 5,000 | 3,500 |
| ,, setigera | 3,500 | 5,000 | — | — | — | — |
| ,, shrubsolei | 190,000 | 165,000 | 9,750 | 12,500 | 2,500 | 3,500 |
| ,, stolterfothii | 2,500 | — | 1,500 | 2,500 | 500 | 2,000 |
| Biddulphia granulosa | 1,500 | — | 2,750 | — | — | — |
| ,, favus | 500 | — | 250 | — | — | — |
| ,, rhombus | 1,000 | — | — | 5,000 | — | — |
| Coscinodiscus radiatus | 7,500 | — | 5,500 | 10,000 | 1,000 | — |
| Guinardia flaccida | 285,000 | 1,800,000 | 34,500 | — | 3,000 | 171,000 |
| Bacteriastrum sp. | 3,000 | 300,000 | 750 | 37,500 | 9,000 | — |
| Bacillaria paradoxa | — | — | — | 12,500 | — | — |
| Nitzschia seriata | 1,000 | — | 3,000 | 12,500 | — | — |
| Streptotheca thamensis | — | — | 1,500 | — | — | — |
| Bellerochea malleus | 500 | — | — | — | — | — |
| Ceratium furca | 71,000 | 2,000 | 250 | 12,500 | 1,000 | — |
| ,, fusus | 690,000 | 31,000 | 124,000 | 225,000 | 6,000 | 1,000 |
| ,, tripos | 140,000 | 2,625 | 7,000 | 170,000 | 10,000 | 2,500 |
| Peridinium sp. | 2,000 | — | 250 | 10,000 | 1,500 | 1,000 |
| Trochiscia sp. | 3,750 | 370 | 7,700 | — | — | — |
| Distephanus sp. | 1,000 | — | — | — | — | — |
| Tintinnopsis sp. | 3,000 | — | — | 2,500 | — | — |
| Noctiluca miliaris | 27,000 | 183,000 | 54,000 | 22,500 | 140,000 | 138,000 |
| Pleurobrachia pileus | 1 | — | — | 2 | 2 | 8 |
| Medusoid gonophores | 20 | 37 | 5 | 200 | 160 | 15 |
| Plutei of Echinoderms | 1,510 | — | — | 1,250 | — | — |
| Sagitta bipunctata | 40 | 300 | 5 | 1,000 | 700 | 300 |
| Larval Polychæta | 3,100 | 200 | 3,750 | 7,800 | 560 | 530 |
| 'Mitraria' | — | 15 | 500 | — | — | 200 |
| Crab zoea | — | 37 | — | — | 3 | — |
| ,, megalopa | — | — | — | — | — | 2 |
| Mysis stage of Crangon | — | 37 | 2 | — | 1 | 75 |
| Podon intermedium | — | — | — | 40 | 20 | — |
| Calanus helgolandicus | — | — | — | — | 5 | 4 |
| Pseudocalanus elongatus | 20 | 300 | 5 | — | — | — |
| Temora longicornis | 230 | 1,400 | 350 | 160 | 160 | 2,500 |
| Centropages hamatus | 100 | 110 | 310 | 60 | 60 | 400 |
| Anomalocera pattersoni | — | — | — | — | 1 | — |
| Acartia clausi | 130 | 600 | 125 | 100 | 500 | 900 |
| Oithona similis | 2,530 | 5,000 | 520 | 12,500 | 11,400 | 16,000 |
| Paracalanus parvus | 50 | 700 | 10 | 1,000 | 4,000 | 2,300 |
| Isias clavipes | — | 900 | 20 | — | 20 | 30 |
| Copepod nauplii | 15,000 | 35,000 | 12,800 | 20,000 | 6,500 | 3,500 |
| ,, juv. | 6,000 | 55,000 | 8,215 | 7,500 | 175,000 | 18,500 |
| Gasteropods, larval | 500 | — | 750 | 1,250 | — | — |
| *Lamellibranchs*, larval | 500 | 1,000 | 4,250 | 2,500 | 4,500 | 3,500 |
| *Oikopleura sp.* | 1,580 | 4,000 | 3,000 | 2,560 | 1,000 | 3,400 |
| *Ascidian eggs* | 1,500 | 370 | — | — | — | 100 |

Station and Date.—Hensen Net Stations, October 7th and November 18th, 1907.

| | | | | | | |
|---|---|---|---|---|---|---|
| ısed | — | — | — | — | — | — |
| h in fathoms | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 | 10-0 |
| ı in c.cm. | 3½ | 17 | 5 | 3½ | 3 | 2 |
| ons | I. | II. | III. | I. | II. | III. |
| ulphia mobiliensis | 200 | 50 | 275 | 450 | 3,900 | 11,000 |
| oceros contortum | 50 | — | — | 2,000 | 150 | 100 |
| , debile | 250 | — | — | 500 | 75 | 50 |
| . decipiens | 350 | — | 100 | 17,500 | 1,600 | 750 |
| . teres | 1,000 | 250 | — | 6,000 | 375 | 450 |
| . densum | 750 | 750 | 325 | 1,250 | 600 | 400 |
| , boreale | 1,500 | 250 | — | — | — | — |
| , subtile | 300 | — | — | 750 | — | — |
| nodiscus concinnus | 1,000 | 100 | 225 | 5,550 | 750 | 1,500 |
| ium brightwellii | 100 | — | — | — | — | 50 |
| mpia zodiacus | 50 | — | — | 1,000 | 75 | 450 |
| ocylindrus danicus | — | — | — | 75 | — | — |
| ıira borreri | 200 | — | — | — | — | 50 |
| osigma sp. | — | — | — | — | 25 | — |
| osolenia semispina | 9,000 | 750 | 25 | 1,000 | 750 | 150 |
| ,, setigera | 1,850 | — | — | 150 | 300 | 250 |
| ,, shrubsolei | 1,100 | — | 25 | 600 | — | 250 |
| eria borealis | — | — | — | — | — | 50 |
| laria paradoxa | 400 | — | 20 | 250 | 75 | — |
| ·iastrum sp. | 5,750 | 5,200 | 175 | 4,250 | 1,125 | 980 |
| ılphia rhombus | 300 | — | — | 150 | 25 | — |
| ,, granulosa | — | — | — | 75 | 150 | — |
| ,, favus | — | — | — | — | 25 | — |
| nodiscus granii | — | — | — | 190 | 75 | 100 |
| ,, radiatus | 150 | 250 | 25 | — | 225 | 100 |
| ardia flaccida | — | 50 | 75 | 75 | 75 | 100 |
| ium furca | — | — | — | 225 | 75 | — |
| , fusus | 750 | 250 | 125 | 975 | 375 | 650 |
| , tripos | 8,650 | 50 | 825 | 2,700 | 1,720 | 1,500 |
| sterias sp. | 50 | — | — | — | — | — |
| ıiscia sp. | 100 | — | — | — | 75 | — |
| nnopsis sp. | 300 | 1,750 | 25 | 250 | — | — |
| luca miliaris | 10,000 | 100,000 | 7,800 | 1,300 | 1,335 | 500 |
| obrachia pileus | — | 3 | — | 1 | — | — |
| soid gonophores | 1 | 10 | 3 | 10 | 2 | 6 |
| i of Echinoderms | — | 250 | — | — | — | — |
| ta bipunctata | 6 | 250 | 200 | 35 | 30 | 16 |
| lytus prolifer | 1 | — | — | — | — | — |
| ıl Polychæta | 580 | 50 | 55 | 225 | 30 | 55 |
| 'aria' | 50 | 250 | 50 | 75 | — | 600 |
| zoea | — | — | 1 | — | — | — |
| megalopa | — | — | 1 | — | — | — |
| stage of Crangon | 1 | — | 5 | 3 | — | — |
| ıus helgolandicu | — | — | — | 15 | 1 | 1 |
| localanus elongatus | 20 | 250 | 130 | 10 | 30 | 35 |
| ıra longicornis | 17 | 50 | 10 | 5 | 4 | 80 |
| opages hamatus | 25 | 50 | — | 5 | 1 | 65 |
| ia clausi | — | 450 | 275 | 85 | 90 | 55 |
| na similis | 2,780 | 1,000 | 2,600 | 3,310 | 2,300 | 530 |
| alanus parvus | 160 | 13,000 | 2,450 | 665 | 425 | |
| clavipes | — | — | 1 | — | — | — |
| pina acutifrons | — | — | — | — | — | 3 |
| pod nauplii | 500 | 500 | 100 | 225 | 225 | 300 |
| juv. | 2,000 | 12,500 | 1,375 | 4,250 | 450 | 350 |
| ropods, larval | 100 | 250 | 50 | 75 | 75 | 100 |
| llibranchs, larval | 650 | 1,750 | 1,000 | 2,625 | 225 | 500 |
| oleura sp. | 480 | 1,600 | 300 | 150 | 10 | 150 |
| ian eggs | — | 250 | — | — | — | — |

# REPORT ON EXPERIMENTS WITH MARKED FISHES DURING THE YEAR, 1907.

(Plates I and II).

By Jas. Johnstone.

It was only possible, for various reasons, to continue these experiments during 1907 on a less extensive scale than during 1905-6. We resolved to concentrate the experiments as far as possible, and to confine our attention to the summer plaice fishery in Liverpool Bay, and to the autumn and winter plaice fishery that is carried on in Red Wharf Bay and in Channel Course. Three experiments were therefore made, (1) in Menai Straits in February, 1907, when about 100 small plaice were caught by the "John Fell" and liberated close to the place of capture; (2) near Nelson Buoy at the entrance to the Ribble Estuary in July, 1907, when about 150 plaice were caught, also by the "John Fell," and liberated on the ground where taken; and (3) in Red Wharf and Beaumaris Bays in October, 1907, where 120 plaice were caught and liberated. I intended to mark and liberate plaice and flounders in the neighbourhood of the Lune and Wyre Rivers, and in Barrow Channel, but did not find this possible because of the other engagements of the "John Fell" and the Fleetwood police cutter. In June a number of plaice which had been kept during the preceding year in the spawning pond, at the Port Erin Hatchery, were turned out into the sea, and at Prof. Herdman's request I sent a number of labels to Mr. Chadwick, Curator of the Biological Station, who then marked 28 large plaice and liberated them near Bradda Head.

During 1907 we, therefore, marked 360 fishes, all plaice with one exception, and at the time of writing (16th

December) 102 of these have been returned to me. In addition to these fishes 47 others marked and liberated during 1905 and 1906 have also been returned, making 149 recaptures in all. No attempt was made to mark other fishes than plaice during 1907, but we hope in the coming year to devote some attention to flounders. As in former years, I am convinced that quite a number of marked plaice are captured and are not reported to me. One hears, now and then, of fish that have been captured for some time, and it is curious that over and over again marked plaice are recaught by the same boats. One could draw up a list of smacks that have caught what is apparently far more than their share of marked fishes, and I am inclined to suspect that many fishes, caught perhaps during the dark, are not noticed. Most of the fishermen on the West Coast of England must now know about these experiments, but it appears that until a skipper has caught one or more marked fish he and his men do not examine their catches so carefully as to avoid the risk of a marked fish going unnoticed.

As before, I am greatly indebted to those who have taken the trouble to send me marked fishes handed to them. This applies particularly to Messrs Harley and Miller, of the Liverpool Fish Market, Messrs Dean and Houldsworth (members of the Committee); Mr. Robert Knox, of Douglas; and Mr. A. J. Rust, of Milford Haven. Captain Jones, Head Bailiff at the Carnarvon Station, has also taken a great amount of trouble to forward me all fish given to him, and has been most careful in supplying all the necessary information of recapture, &c.

I give all the details of recapture in the tables that follow. The "general summary" gives the total results of the experiments of the year, and includes, also, marked fishes which have been liberated in 1905 and 1906. The

following tables give the details of recapture and growth of the fishes returned. The "analyses of sizes of fish recaught" give the numbers of plaice of each size group (every quarter of an inch) marked and liberated; it will be seen that the majority of the plaice dealt with were between 9 and 11 inches in length. In the tables of "particulars of fishes returned" the columns are numbered in order to save space. The headings are:—

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| No. of label | Size when liberated (inches) | Place of recapture | Date of recapture | Months in the Sea | Length when recaptured (inches) | Increase in length (inches) | Method of recapture |

The lengths of the fishes when marked were measured to the nearest quarter of an inch. The lengths when returned were measured to the nearest eighth of an inch. When only one or two fishes are returned in any particular month an error may result from this difference in the accuracy of the two measurements, but when average growth-increments are calculated, and when these are plotted on a curve, and the latter smoothed, such inaccuracies disappear. The place of recapture is usually given as reported to me. It is generally unlikely that it is accurate to within a mile or two, as a fish may be caught anywhere during a drag of the trawl-net, which may be of 20 or more miles in length in the case of a steam trawler. As a rule, however, such inaccuracies in position have no real significance. The values, "months in the sea," have been obtained by subtracting the number of the month of liberation from that of recapture: they are calendar months. The letters under heading 8, "method of recapture," denote: ST, steam

trawler; 1T, 1st class trawler; 2T, 2nd class trawler; SN, stake net; TN, trammel net; DN, draw net or seine net. The greater number of the fishes returned were recaught by means of trawl nets used by 1st and 2nd class trawlers. In some cases this information as to the method of recapture was not given; in one or two cases it was also impossible to trace the position of recapture. Whenever possible the fishes were weighed, but very often they had been gutted before being forwarded, so that it was not practicable to estimate the weight in every case. In the case of every fish sent, the otoliths were removed, and are being kept with the object of determining the mode of growth of these structures in relation to the season.

## GENERAL SUMMARY:—

## STATIONS AND NUMBERS OF FISHES LIBERATED AND RETURNED.

| | Place where Fishes Liberated. | Date. | No. Liberated. | No. Returned. | Percentage Returned. |
|---|---|---|---|---|---|
| 1 | Eastern Entrance to Menai Straits ..... | 6/2/07 | 92 plaice | 29 | 31·5 |
| 2 | 2 miles N. from Bradda Head, Isle of Man ..... | 1/6/07 | 28 plaice | — | — |
| 3 | Near Nelson Buoy, Entrance to Ribble ..... | 3/7/07 | 147 plaice<br>1 brill | 36 | 24·5 |
| 4 | Beaumaris Bay ..... | 24/10/07 | 120 plaice | 37 | 30·8 |
| | Totals, Experiments of 1907 ..... | ..... | 360* | 102 | 28·3† |
| | Experiments of 1906 ..... | ..... | — | 45 | — |
| | Experiments of 1905 ..... | ..... | — | 2 | — |
| | Totals ..... | ..... | — | 149 | — |

* Includes only the fishes liberated on the Lancashire and Welsh coasts.
† Calculated from Lancashire and Welsh experiments only.

## DETAILS OF FISHES RETURNED.

### Experiments of 1906.

The following fishes, returned in 1907, are to be added to the lists given in the last Annual Report.

Experiment 2, 19th February, 1906.

Station: Near Fleetwood. 35 plaice.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L752 | 11¼ | Off Dundalk, E. coast of Ireland | 26/11/06 | 9 | 14 | 2¾ | ST |
| L768 | 11 | Not known ..... | 8/3/07 | 13 | 15⅞ | 4⅞ | — |
| L769 | 9 | 1½ miles E. from Corsewall, Clyde, 12 faths. | 18/4/07 | 14 | 11 | 2 | — |

The results of this experiment were discussed in last year's Report, but several recaptures have been made during the present year and some doubtful cases have been traced. It may be useful, therefore, to summarise the results anew. Eighteen of the 35 plaice liberated, or over 51 per cent., have been returned, and it will be seen that the positions of recapture are distributed over a considerable area, one fish being taken in the Firth of Clyde, and one off the East Coast of Ireland. It will be noticed that a group of eight fishes have been recaught in inshore waters during the four months after the date of liberation. Two of these had migrated to the South, but were recaptured still in shallow water inshore, while six fishes were taken in almost the same place where those liberated were originally caught. Then we have a group of seven fishes recaptured much further offshore and in relatively deep water, and all from seven to ten months after the date of liberation. Finally, three fishes are included in this year's recaptures: one taken near Dundalk, one in the Firth of Clyde, and one taken probably by a steam trawler not far from Morecambe

Bay Lightship. On Plate I these three latter recaptures are indicated by large round spots. I think that the results of this experiment indicate those that might be expected if it were practicable to mark and liberate a very large number of plaice on the inshore grounds during the early months of the year, that is, that these fishes would remain there until the end of the spring, to be caught by the stake-nets or inshore trawlers, and then, as they began to experience the season's growth, they would gradually move offshore into deeper water, and would not again return into the shallow bays and estuaries. Unfortunately, it is not easy to obtain a sufficiently large number of small plaice by trawling in the estuaries during January and February, and I can only suggest that the fish should be caught by stake-nets, and taken alive into Piel Hatchery to be marked.

Experiment 5, 5th March, 1906.

Station: Near Blackpool.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L948 | 13F | Lune, near No. 3 Buoy | 21/9/07 | 18 | ?14 | 1 | DN |
| L949 | 13¼F | Near Arnside, Morecambe Bay. | 21/8/07 | 17 | — | — | — |
| L953 | 9¾ | 20 miles N.E. from Bahama Light Ship, 24 fathoms. | 11/5/07 | 14 | 14½ | 4¾ | 1T |
| L971 | 8¾ | 5 miles E. from Bahama Light Ship. | 30/5/07 | 14 | 11⅞ | 3⅛ | ST |
| L980 | 11F | "Point of Shoals." ..... | 25/3/07 | 12 | 12½ | 1½ | ST |

Experiment 6, 6th March, 1906.

Station: Colwyn Bay.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL21 | 8¼ | E. from Bahama Light. | 19/4/07 | 13 | — | — | 1T |
| LL38 | 8¼ | Red Wharf Bay, 12 fathoms. | 14/12/06 | 9 | 10¾ | 2½ | 1T |

## Experiment 8, 31st March, 1906.

Station: Outside Walney Island.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL103 | 7¾ | 5 miles S.S.E. from Bahama Lightship. | 21/12/06 | 9 | 9¼ | 2 | ST |

## Experiment 10, 12th June, 1906.

Station: Near Nelson Buoy.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL186 | 8½ | 15 miles off Coningbeg Lightship. | 6/7/0/7 | 13 | 12⅝ | 4⅛ | 1T |
| LL187 | 9¼ | Off Eastham, River Mersey, 11 fathoms. | 19/12/06 | 6 | 11⅛ | 1⅞ | 2T |
| LL190 | 9½ | Not known ..... | 22/1/07 | 7 | — | — | — |
| LL192 | 8¾ | 6 miles S. from Bahama Light Ship. | 22/12/06 | 6 | ?10 | 1¼ | ST |
| LL198 | 8½ | 10 miles S.S.E. from Mine Head, S. coast Ireland. 38 fathoms. | 17/3/07 | 9 | 12⅝ | 4⅛ | 1T |
| LL204 | 8¼ | S.W. from Caldy Island, 26 fathoms. | 1/8/07 | 14 | 12⅜ | 3⅞ | 1T |

## Experiment 15, 9th July, 1906.

Station: Near Nelson Buoy.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL261 | 8½ | Off Kinsale Head to S.E. by E., 46 fathoms. | 8/4/07 | 19 | 10¾ | 2¼ | ST |
| LL266 | 9¼ | Off Nelson Buoy, 9 faths. | 12/6/07 | 11 | 10¾ | 1½ | 2T |
| LL269 | 9 | Off Caldy Island. ..... | 4/7/07 | 12 | 11⅝ | 2⅝ | 1T |
| LL276 | 8½ | 4 miles N.W. from Nelson Buoy. | 12/6/07 | 11 | ?10 | 1½ | 1T |
| LL280 | 9 | 6 miles S.S.W. from Morecambe Bay Light Ship. | 23/7/07 | 12 | ?13 | 4 | 1T |
| LL289 | 8¼ | 6 miles S.E. from Bahama Light Ship | 9/12/06 | 5 | 10½ | 2¼ | ST |
| LL297 | 8¼ | 2 miles E. from Liverpool Bar Light Ship. | 7/7/07 | 12 | 10¾ | 2½ | 1T |

The results of Experiments 10 and 15 of 1906 also confirm the conclusion that the plaice reared on the Lancashire shallow water grounds move offshore with increasing age and do not return. The recaptures in 1907 from these two experiments are indicated on Plate II by the black spots, and it will be seen that of the plaice liberated in 1906 near Nelson Buoy only two were recaught on nearly the same grounds in 1907. On the other hand, two of these plaice were recaught in 1907 to the S.E. off Maughold Head; and six have been recaught off the S.E. coast of Ireland. All the latter are, compared with the plaice recaught off Nelson Buoy (the ground of original capture), large fishes. One fish, the inevitable exception to the others, was found in the River Mersey, as far up as Eastham.

Experiment 11, 13th June, 1906.

Station: Near Pwllheli.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL208 | 9¾ | S.W. from Godreooy, S. coast of Ireland, 20 fathoms. | 15/2/07 | 8 | 12¼ | 2½ | — |

This fish is one of a lot of 40 set free in Tremadoc Bay in the summer of 1906. So far, only three fishes have been recaptured; one near the place of liberation, and two off the Irish coast.

Experiment 12, 14th June, 1906.

Station: Off Llanrhystyd, Cardigan Bay.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL247 | 11½ | 10 miles S. by W. from Coningbeg Light Ship, 38 fathoms. | 7/7/07 | 13 | 12 | ½ | ST |
| LL334 | 8½ | 4 miles W.N.W. from Aberayron Cardigan. Bay. | 26/4/07 | 10 | 9¾ | 1¼ | 1T |
| LL337 | 7¾ | Carmarthen Bay, 3-4 fathoms. | 18/4/07 | 10 | 9¼ | 1½ | 2T |

**Experiment 13, 16th June, 1906.**

**Station: Off Dinas Head, Pembrokeshire.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL356 | 14 | 4 miles N.N.W. from Aberayron, Cardigan Bay. | 20/4/07 | 10 | 14 | 0 | 1T |
| LL351 | 13¾ | Newport Bay, 7-8 faths. | 5/6/07 | 12 | 14¾ | 1 | 1T |

**Experiment 16, 12th July, 1906.**

**Station: Off Penkilan, Tremadoc Bay.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL411 | 8¾ | Near Caldy Island, 20 fathoms. | 10/9/07 | 14 | 11⅞ | 3⅛ | 1T |
| LL415 | 9 | Pinfold Channel, 2 faths. | 18/1/07 | 6 | 10⅝ | 1⅜ | 2T |
| LL434 | 8½ | Dinas Head, bearing W.S.W., 12 fathoms. | 22/6/07 | 11 | 11 | 2⅛ | ST |

**Experiment 17, 19th September, 1906.**

**Station: Red Wharf Bay.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL440 | 11¼ | 2 miles from St. Patrick's Island. | 22/10/07 | 13 | 14⅝ | 3⅛ | H |
| LL446 | 10¼ | Red Wharf Bay ..... | 10/1/07 | 4 | — | — | HN |
| LL450 | 10¾ | Holyhead Outer Harbour | 25/1/07 | 4 | 11¼ | ⅛ | TN |
| LL457 | 10 | Conway Bay, 7 fathoms. | 20/10/07 | 13 | 13¼ | 3¼ | 1T |
| LL459 | 9¼ | Menai Straits ..... | 5/3/07 | 6 | 9¼ | ⅛ | 2T |
| LL463 | 10 | Holyhead Outer Harbour. | 12/1/07 | 4 | 10⅜ | ⅛ | TN |
| LL465 | 9 | Red Wharf Bay ..... | 19/12/06 | 3 | 9¼ | ⅛ | 1T |

These recaptures are indicated in Plate I as red spots. It will be seen that six of the plaice in question

have apparently remained in the neighbourhood of their original place of capture. Five of them were caught at the beginning of this year, or at the end of last year, but one was taken in almost the place where liberated a complete year afterwards. One had crossed the Irish Sea, and was caught off the coast of Ireland.

### Experiment 18, 3rd October, 1906.

Station: Luce Bay.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL493 | 12 | Luce Bay ..... | 7/5/07 | 7 | 12¾ | ¾ | DN |
| LL497 | 12¼ | Luce Bay ..... | 19/7/07 | 9 | 13¼ | 1 | DN |
| LL500 | 11½ | 15 miles S.E. from Maughold Head, I.O.M. | 27/2/07 | 4 | 11½ | 0 | 1T |
| LL505 | 13½ | (?) Off Dhu Hearteach, W. coast of Scotland. | 25/4/07 | 6 | 13½ | 0 | ST |
| LL517 | 13 | Near Denure Harbour, Firth of Clyde. | 20/11/07 | 13 | 15½ | 2½ | — |

These recaptures exhibit nothing noteworthy. Plaice No. LL505 is recorded just as received, though I think it extremely doubtful whether the information as to the place of recapture is accurate.

### Experiment 21, 13th October, 1905.

Station: Luce Bay.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| L872 | 10¼ | Luce Bay ..... | 20/9/07 | 23 | 15¼ | 5 | TN |

The following fish was reported to me, but the label (which alone was sent) was entirely corroded away, so that only the silver wire and the bone button were attached to the fish when caught. It is probably one of the Luce Bay fishes liberated in 1904 or 1905.

| 1 | 2 | 3 | 4 | 5 | 5 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| — | — | 4 miles S.W. from Girvan Harbour, Firth of Clyde. | 7/1907 | — | — | — | — |

## Experiments of 1907.

### Experiment 1, 6th February, 1907.

Station: At Eastern Entrance to Menai Straits.

All the fish caught in Menai Straits, and in Beaumaris Bay.

Analysis of Sizes of Fishes Liberated.

| Size (inches) | 7¼ | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 3 | 9 | 10 | 14 | 11 | 10 | 10 |

| Size (inches) | 9¼ | 9½ | 9¾ | 10 | 10½ | 10¾ | 11 | — |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 3 | 4 | 6 | 5 | 3 | 1 | 1 | — |

## Particulars of Fishes Returned.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL536 | 10 | 5 miles N.W. from Jumbo Buoy, 9 fathoms | 12/6/07 | 4 | 10⅞ | ⅞ | 2T |
| LL537 | 8¼ | Off Holyhead Breakwater, 8 fathoms. | 30/3/07 | 1 | 9 | ¾ | TN |
| LL551 | 8½ | Dinas Head, bearing W.S.W., 12 fathoms. | 20/6/07 | 4 | 9½ | 1½ | 1T |
| LL554 | 9¾ | Carnarvon Bay ..... | 13/6/07 | 4 | 10¼ | 1 | 1T |
| LL558 | 8 | 8 miles S. by W. from Morecambe Bay Light Ship. | 22/8/07 | 6 | 10 | 2 | 2T |
| LL559 | 10½ | Off Friars, below Beaumaris, 3 fathoms. | 30/11/07 | 9 | 13⅞ | 3⅜ | 2T |
| LL563 | 10½ | Penrhyn Fish Weirs, Menai Straits. | 11/5/07 | 3 | 11½ | 1 | — |
| LL569 | 9½ | Red Wharf Bay ..... | 5/12/07 | 7 | 11⅜ | 2½ | 1T |
| LL570 | 9½ | Between Newcome Knoll and Deposit Buoy, Entrance to Mersey. | 11/10/07 | 8 | 12⅞ | 3⅜ | — |
| LL572 | 8½ | Between Point Lynus and Great Ormes Head, 15 fathoms. | 14/11/07 | 9 | 12¼ | 3¾ | 1T |
| LL577 | 8¾ | Conway Bay, 7 fathoms. | 2/11/07 | 9 | — | — | 2T |
| LL582 | 8¼ | Between Point Lynus and Great Ormes Head, 15 fathoms. | 23/10/07 | 8 | 9¾ | 1½ | 1T |
| LL589 | 9¾ | Between Beaumaris and Gallows Point, in Menai Straits. | 14/3/07 | 1 | 9¾ | 0 | 2T |
| LL595 | 7¾ | Carnarvon Bay ..... | 13/6/07 | 4 | 9½ | 1¾ | 1T |
| LL596 | 8 | 2 miles N. from N.W. Buoy. | 11/6/07 | 4 | 9 | 1 | 2T |
| LL598 | 8¼ | Red Wharf Bay, 10-11 fathoms. | 3/12/07 | 10 | 11⅞ | 3⅜ | 1T |
| LL651 | 9½ | 8 miles N. from Morecambe Bay Light Ship. | 27/2/07 | 0 | 9¾ | ¼ | 1T |
| LL652 | 9 | Off Deposit Buoy. 5 fathoms. | 9/9/07 | 7 | 12¼ | 3¼ | 2T |
| LL653 | 8¾ | Red Wharf Bay, 11-12 fathoms. | 3/12/07 | 10 | 10½ | 1¾ | 1T |
| LL657 | 8½ | Between Point Lynus and Great Ormes Head. 20 fathoms. | 12/11/07 | 9 | 10⅜ | 2⅛ | 1T |
| LL658 | 11 | 5 miles W.S.W. from Nelson Buoy | 27/9/07 | 7 | 13 | 2 | 1T |
| LL659 | 8¼ | Off Dinorwic, Menai Straits | 1/3/07 | 1 | 8¾ | ½ | 2T |
| LL660 | 9 | Red Wharf Bay ..... | 4/10/07 | 8 | 11½ | 2½ | 1T |
| LL663 | 9 | Red Wharf Bay ..... | 8/12/07 | 7 | 14 | 5 | 1T |
| LL664 | 7¾ | Off Beaumaris Pier, 4 fathoms. | 25/10/07 | 8 | 10½ | 2¾ | DN |
| LL667 | 8½ | 10-20 miles S.E. from Bahama Light Ship. | 20/7/07 | 5 | 10 | 1½ | 1T |
| LL668 | 8 | Between Beaumaris and Gallow Point, in Menai Straits, 3 fathoms. | 14/3/07 | 1 | 8¼ | ¼ | 2T |
| LL669 | 8¼ | 2 miles N.W. from W. Constable Buoy, 13 fathoms. | 7/7/07 | 5 | 10½ | 2¼ | 1T |
| *LL673* | 7¾ | Lavan Sands ..... | 16/10/07 | 8 | — | — | SN |

Thus 92 plaice were liberated in the entrance to Menai Straits in February, 1907, and at the end of the same year 29, or about 31½ per cent., have been returned. The results of the experiment are represented in Plate I, and it will be seen that the recoveries fall roughly into three groups: (1) four fishes caught in Menai Straits during the four months after the date of liberation; (2) eight fishes caught in Liverpool Bay during the summer and autumn; and (3) a group of ten fishes caught in Red Wharf Bay and Channel Course during the late autumn and winter of 1907. One fish was taken in Holyhead Outer Harbour in a trammel net, two fishes were caught in Carnarvon Bay in June, and one fish went as far South as Dinas Head in Pembrokeshire, where it was caught, also in June. Immediately after liberation one fish migrated to the North, and was recaught not far from Morecambe Bay Light Ship.

## Experiment 2, 1st June, 1907.

Station: Two miles North from Bradda Head, Isle of Man. The plaice marked in this experiment were part of the stock of "spawners" kept during the preceding winter and spring at the Port Erin Hatchery.

### Analysis of Sizes of Fishes Liberated.

| Size (inches) | 12 | 12¼ | 12¾ | 13 | 13¼ | 13½ | 13¾ | 14¼ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 4 |

| Size (inches) | 14½ | 15¼ | 15½ | 15¾ | 16 | 16¾ | 19 | 19½ |
|---|---|---|---|---|---|---|---|---|
| No. of plaice | 4 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |

None of these plaice have yet been returned. The fishes were marked and liberated by Mr. H. C. Chadwick, of the Port Erin Biological Station. I think it possible that the fishes were enfeebled as a result of long confinement in the spawning pond, and did not survive the marking operation and subsequent handling.

### Experiment 3, 3rd July, 1907.

Station: Near Nelson Buoy, Entrance to Ribble Estuary.

Fish caught near Nelson Buoy.

ANALYSIS OF SIZES OF FISHES LIBERATED.

| Size (inches) | 7¼ | 7½ | 7¾ | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 1 | 1 | 8 | 19 | 25 | 24 | 14 | 9 | 4 |
| No. of brill | — | — | — | — | — | — | — | — | — |

| Size (inches) | 9½ | 9¾ | 10 | 10¼ | 10¾ | 11 | 11½ | 11¾ | — |
|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 15 | 2 | 9 | 8 | 3 | 2 | 2 | 1 | — |
| No. of brill | — | — | — | — | — | 1 | — | — | — |

PARTICULARS OF FISHES RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL689 | 9½ | Ribble Bar, 6 fathoms. H.W. | 2/12/07 | 5 | 10⅛ | ⅝ | 2T |
| LL691 | 8¼ | 6 miles N.W. from N.W. Buoy, 6 fathoms. | 11/10/07 | 3 | 10 | 1¾ | 2T |
| LL695 | 10¼ | Heysham Lake, in shallow water. | 22/8/07 | 1 | 11 | ¾ | DN |
| LL696 | 8 | 1 mile W. from Jumbo Buoy, 6½ fathoms. | 10/11/07 | 4 | 10¼ | 2¼ | 2T |
| LL704 | 7¾ | "Morecambe Bay" ..... | 11/8/07 | 1 | 8⅛ | ⅜ | 1T |
| LL709 | 11½ | Off Nelson Buoy, 17 faths.. | 14/8/07 | 1 | — | — | 1T |
| LL711 | 10 | 7 miles N.W. from Liverpool N.W. Light Ship, 15 fathoms. | 4/8/07 | 1 | 10⅜ | ⅜ | 1T |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LL713 | 8¾ | 3 miles W. from Nelson Buoy. | 27/7/07 | 0 | 9 | ½ | 2T |
| LL717 | 8½ | Liverpool Bar Light Ship bearing S. by E., 15 miles distant, 15 faths. | 24/7/07 | 0 | 8¾ | ½ | 1T |
| LL720 | 8½ | 2 miles S.W. from Nelson Buoy, 10 fathoms. | 13/9/07 | 2 | 9 | ½ | 2T |
| L' 726 | 8¾ | 12miles N.W. from Liverpool Bar Light Ship, 15 fathoms | 8/9/07 | 2 | 9½ | ¾ | 1T |
| LL730 | 8½ | Off Nelson Buoy, 14 faths. | 2/8/07 | 1 | 8¾ | ½ | 1T |
| LL732 | 8¼ | Roosebeck, Morecambe Bay. | 20/11/07 | 4 | 9 | ¼ | SN |
| LL737 | 8¼ | 10 miles N. from Liverpool Bar Light Ship, 14 fathoms. | 13/8/07 | 1 | 8⅞ | ⅜ | 1T |
| LL752 | 7¾ | 3 miles N. from N.W. Buoy, 6 fathoms. | 30/8/07 | 1 | 9½ | 1⅜ | 2T |
| LL758 | 8½ | Off Nelson Buoy, 17 faths.. | 15/8/07 | 1 | 8⅝ | ⅛ | 1T |
| LL763 | 10¾ | 5 miles W.S.W from Morecambe Bay Light Ship. | 13/7/07 | 0 | — | — | 1T |
| LL764 | 10¼ | 10 miles N. from Liverpool Bar Light Ship, 15 fathoms. | 6/8/07 | 1 | 10½ | ½ | 1T |
| LL767 | 8½ | 2 miles N.W. from N.W. Buoy, 6 fathoms. | 24/10/07 | 3 | 10⅛ | 2 | 2T |
| LL768 | 9½ | 12 miles from N W Light Ship, 17 fathoms. | 20/7/07 | 0 | 9⅝ | ⅛ | 1T |
| LL772 | 9¾ | 10 miles N.W. from Liverpool Bar Light Ship, 19 fathoms. | 25/8/07 | 1 | 10⅞ | 1⅛ | 1T |
| LL781 | 10 | 2 miles W. from Nelson Buoy. | 10/7/07 | 0 | 10 | 0 | 2T |
| LL782 | 9 | S. Side of Ribble..... | 9/11/07 | 4 | 11 | 2 | SN |
| LL783 | 8¾ | East Hoyle Bank ..... | 20/11/07 | 4 | 11 | 2½ | SN |
| LL792 | 8 | 15 miles N.N.W. from Liverpool Bar Light Ship, 17 fathoms. | 5/8/07 | 1 | 8⅛ | ⅛ | 1T |
| LL799 | 8½ | Ribble, near Pinfold Buoy, 3 fathoms. | 4/12/07 | 5 | 10½ | 1⅜ | 2T |
| LL806 | 8½ | 12 miles N.W. from Nelson Buoy, 17 faths. | 11/8/07 | 1 | 8½ | 0 | 1T |
| LL810 | 8½ | Off Nelson Buoy, 14 faths.. | 2/8/07 | 1 | 9 | ½ | 1T |
| LL813 | 7¾ | 3 miles W. from Jumbo Buoy. | 30/11/07 | 4 | — | — | 2T |
| LL814 | 8¾ | Near Lytham Pier ..... | 16/11/07 | 4 | 9½ | ⅛ | 2T |
| LL817 | 8½ | Near No. 5 Buoy n Lune.. | 29/11/07 | 4 | 10½ | 2½ | 2T |
| LL820 | 8¾ | 2 miles N W from N.W. Buoy 6 fathoms. | 24/10/07 | 3 | 9¾ | 1 | 2T |
| LL822 | 8½ | Near Jumbo Buoy ..... | 26/8/07 | 1 | — | — | 2T |
| LL823 | 8¼ | 4 miles N.E. from Liverpool Bar Light Ship, 9 fathoms. | 14/10/07 | 3 | 9½ | 1 | 1T |
| LL824 | 10 | Off Nelson Buoy, 9 faths.. | 28/9/07 | 2 | — | — | 2T |
| LL827 | 8 | 7 miles N. from N.W. Light Ship, 15 fathoms | 6/11/07 | 4 | — | — | 1T |

We see that 147 plaice were liberated in this experiment and that 36, or about 24½ per cent. have been recaught up to the present time. In the corresponding experiments of last year on this station 90 plaice in all were liberated, and if we consider the recaptures of this year we find that 42 of these fishes have now been accounted for, that is 46½ per cent., so we may expect that a number of the fishes liberated in July, 1907, will yet be recaptured. As in former years, most of the fishes liberated near Nelson Buoy in the summer months are recaptured on the fishing grounds to the S. and W., only six fishes have been taken close inshore, and there is a rough indication of a migration to the South and West during the summer and autumn months. It is well known that there is a very intense plaice fishery on the fishery grounds lying roughly between the Liverpool N.W. Light Ship and the Morecambe Bay Light Ship during the months July to October, that is, plaice are very abundant here during the period in question. Now we may ask, where do these fishes come from? and only an imperfect answer to this question is afforded by the results of marking experiments. But if we refer to Plate I, representing the results of Experiment 1, 1907, it will be seen that a number of the fishes set free in the Menai Straits in February, 1907, have been recaught on the fishing grounds to the W. and S. from Nelson Buoy. I have no doubt that the majority of the fish caught here have migrated out from the shallow water grounds in the bays and estuaries during the spring months, and that the migration is a feeding one, since one finds that the plaice caught there during the summer and autumn fishery always have their stomachs full of food. The results of Experiment 2 of 1906 also lead to the same conclusion, for we find (see Plate I) that some of the fishes caught in the

Lune and Wyre and liberated in February near the place of capture were recaptured during the summer months on the grounds W. from Nelson Buoy. Convincing proof of this offshore migration from the shallow water rearing grounds in the Morecambe Bay area, or in Liverpool Bay, could, of course, be obtained by marking a reasonably large number of fish caught close inshore, but such an experiment would not be easy to carry out unless the fish could be obtained otherwise than by trawling.

## Experiment 4, 24th October, 1907.

Station: In Beaumaris Bay, just outside a line from Puffin Island to Great Ormes Head.

Fish caught in Menai Straits and in Beaumaris Bay.

ANALYSIS OF SIZES OF FISHES LIBERATED.

| Size (inches) | 8 | 8¼ | 8½ | 8¾ | 9 | 9¼ | 9½ | 9¾ | 10 | 10¼ |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 3 | 3 | 4 | 4 | 17 | 9 | 14 | 10 | 16 | 8 |

| Size (inches) | 10½ | 10¾ | 11 | 11¼ | 11½ | 11¾ | 12 | 12¼ | 12¾ | — |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of plaice | 8 | 4 | 6 | 3 | 3 | 1 | 3 | 2 | 2 | — |

PARTICULARS OF FISHES RETURNED.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| LL631 | 10¼ | Mostyn Deep, Dee | 22/11/07 | 1 | 10¼ | 0 | 2T |
| LL634 | 9 | Conway Bay, 6 fathoms... | 30/10/07 | 0 | 9 | 0 | 1T |
| LL639 | 10½ | Red Wharf Bay, 7 faths... | 25/11/07 | 1 | 10½ | 0 | 1T |
| LL644 | 11 | Conway Bay, 6 fathoms... | 28/10/07 | 0 | 11⅛ | ⅛ | 2T |
| LL650 | 9¼ | Near Puffin Island, 8 fathoms. | 30/11/07 | 1 | — | — | 1T |
| LL852 | 11½ | — | — | — | 12⅛ | ⅛ | |
| LL855 | 12 | Red Wharf Bay, 6 faths... | 24/11/07 | 1 | 12 | 0 | 1T |
| LL861 | 10¼ | Between Point Lynus and Great Ormes Head, 10 fathoms. | 18/11/07 | 1 | — | — | 1T |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LL862 | 10 | Red Wharf Bay, 10 faths.. | 3/12/07 | — | — | — | 1T |
| LL863 | 10 | Between Point Lynus and Great Ormes Head, 15 fathoms. | 14/11/07 | 1 | 10¼ | ¼ | 1T |
| LL864 | 9¼ | Between Point Lynus and Puffin Island, 9 faths. | 18/11/07 | 1 | 9⅜ | ⅛ | 1T |
| LL874 | 9¼ | Conway Bay, 4 fathoms... | 28/10/07 | 0 | 10 | ¼ | 2T |
| LL871 | 10⅞ | Red Wharf Bay, off Moelfre, 5 fathoms ..... | 12/12/07 | 2 | 10⅞ | ⅛ | 1T |
| LL884 | 10¼ | Red Wharf Bay, 10 faths. | 3/12/07 | 2 | 10¼ | 0 | 1T |
| LL886 | 9½ | Red Wharf Bay, 8 faths. | 12/12/07 | 2 | 9⅝ | ⅜ | 1T |
| LL887 | 10 | Between Point Lynus and Great Ormes Head, 15 fathoms. | 12/11/07 | 1 | 10 | 0 | 1T |
| LL888 | 9 | Between Point Lynus and Great Ormes Head, 15 fathoms. | 14/11/07 | 1 | 9⅛ | ⅛ | 1T |
| LL892 | 10 | Red Wharf Bay, 7 faths... | 25/11/07 | 1 | 10 | 0 | 1T |
| LL893 | 9 | Red Wharf Bay, 10-12 fathoms. | 4/12/07 | 2 | 9½ | ½ | 1T |
| LL894 | 9 | Conway Bay ..... | 31/10/07 | 0 | — | — | 1T |
| LL899 | 8½ | Red Wharf Bay, 11 faths.. | 12/12/07 | 2 | 8⅝ | ⅛ | 1T |
| LL900 | 8¼ | Between Point Lynus and Great Ormes Head, 9 fathoms. | 19/11/07 | 1 | — | — | 1T |
| LL901 | 8 | Off Great Ormes Head, 24 fathoms. | 21/11/07 | 1 | 8¼ | ¼ | 1T |
| LL902 | 8½ | Red Wharf Bay, off Buoy, 10 foot Bank. | 12/12/07 | 2 | 8½ | 0 | 1T |
| LL908 | 9¾ | Off Red Wharf Bay, 10 fathoms. | 3/12/07 | 2 | 10 | ¼ | 1T |
| LL913 | 11 | Red Wharf Bay, 10-12 fathoms. | 2/12/07 | 2 | 11 | 0 | 1T |
| LL914 | 10¼ | Off Great Ormes Head, 20 fathoms. | 7/12/07 | 2 | 10⅜ | ⅛ | 1T |
| LL921 | 10 | Off Ormes Head, 20 fathoms. | 5/12/07 | 2 | 10½ | ½ | 1T |
| LL930 | 10 | Conway Bay, 5 fathoms... | 22/11/07 | 1 | 10 | 0 | 2T |
| LL931 | 10½ | Off Puffin Island, 10 fathoms. | 5/12/07 | 2 | 10⅛ | ⅛ | 1T |
| LL933 | 9¾ | Red Wharf Bay, 10-12 fathoms. | 3/12/07 | 2 | 10⅜ | ⅜ | 1T |
| LL936 | 9¾ | Mostyn Deep, Dee..... | 23/11/07 | 1 | 9¾ | 0 | 2T |
| LL938 | 10 | Red Wharf Bay, 10 faths.. | 8/12/06 | 2 | 10 | 0 | 1T |
| LL940 | 9 | Off Red Wharf Bay, 10 fathoms. | 3/12/07 | 2 | 9 | 0 | 1T |
| LL942 | 9 | Red Wharf Bay, 12 faths.. | 3/12/07 | 2 | 9⅜ | ⅜ | 1T |
| LL943 | 10 | Near Puffin Island, 9 fathoms. | 1/12/07 | 2 | 10½ | ½ | 1T |
| LL950 | 9¼ | Wild Roads, off Greenfield, Dee. | 13/12/07 | 2 | 9¼ | 0 | 2T |

Experiment 4 was made about the end of October, just before the beginning of the plaice fishery, which usually sets in in the autumn and early winter in Red Wharf Bay

and in Channel Course. One hundred and twenty plaice were marked and liberated, and up to the time of writing 37 of these have been returned to me—that is, in less than two months nearly 31 per cent. of these fishes have been recaught. The results of this experiment are represented in Plate II, and it will be seen that, with a few exceptions, all the fishes returned have been caught in the immediate neighbourhood of the place of liberation. Three plaice have migrated off shore, and three have travelled along the coast, and have been recaught in the Dee. The large red spots on the Chart represent the recapture of fish liberated in Red Wharf Bay in September, 1906, but of these five were recaught at the end of that year and the beginning of 1907, and only one plaice caught in the present season's fishing belongs to last year's lot. We may conclude then that the stock of plaice appearing in the autumn in the Red Wharf Bay area of each year represents a new stock, and it is very probable that there are plaice which have migrated out from the shallow waters along the North Wales coast and from Menai Straits, since there are no indications from these marking experiments of a migration into this area from the shallow water nurseries on the Lancashire coast.

The results of this experiment indicate a great intensity of fishing on the coast of North Wales during the autumn and early winter. We know that this is the case apart altogether from the results of the marking experiments, and it appears from the returns of fish landed at Bangor that the present autumn and winter (1907) has been quite exceptional with regard to the amount of fishing in Red Wharf Bay and Channel Course. One would naturally conclude from the fact that over 30 per cent. of the plaice marked and liberated have been recaught within two months that the fishing had been very intense;

or it may be said that the percentage of these plaice recaught depends entirely on the amount of fishing being carried on in the neighbourhood of the place of liberation. But it is obvious that these two statements mean exactly the same thing.

### Influence of Different Methods of Fishing.

Most of the marked fishes returned during 1907 were caught by 1st and 2nd class sailing trawlers. The following list is compiled from the tables of particulars of fishes returned:—

| | |
|---|---|
| Caught by 1st class sailing trawlers ... ... | 78 |
| Do. 2nd class do. ... ... | 36 |
| Do. steam trawlers ... ... ... | 10 |
| Do. trammels, stake nets, "draw nets," &c. | 15 |
| Information not given, or doubtful ... ... | 10 |

### Rate of Growth of Marked Plaice.

Only the results of Experiment 1 in 1907 can be utilised to deduce the variation in the rate of growth from month to month throughout the year. The numbers of fishes returned during the separate months were, however, small, and it does not appear useful to tabulate them here. I have examined the numbers, and the results are very much the same as those given in the last annual report, except that the increase in growth during the summer months does not appear to have been as rapid as is represented in the curve given in the last annual report. The numbers of fishes returned are, however, too small to justify any general conclusions as to a difference in the rate of growth between then and former years.

EXPERIMENT I (Black)
EXPERIMENT II 1906. (Red)

Large circles indicate the positions where the fishes are liberated

J.J. del.

## Explanation of the Charts.

### Plate I.

Represents the results of Experiment 2, 1906, and Experiment 1, 1907. The small red circles indicate the approximate places of recapture of the plaice returned during 1906; the filled-in red circles indicate the positions of recapture of the plaice liberated in this experiment and recaptured during 1907. The numbers within the circles, or outside them in the cases of the 1907 recaptures, indicate the months in which the fishes were recaught. The straight lines do not indicate migration paths, but relate the fish recaptured to their positions of liberation.

### Plate II.

Represents the results of Experiments 3 and 4, 1907. The open black circles relate to the plaice liberated off Nelson Buoy in July, 1907. The filled-in black circles indicate the approximate positions of recapture of plaice liberated near Nelson Buoy in 1906 and recaptured in 1907. The open red circles indicate the positions of recapture of the plaice liberated in Beaumaris Bay in October, 1907. The filled-in red circles indicate the recaptures of plaice liberated in Red Wharf Bay in September, 1906, and recaught either at the end of last year or during 1907.

In both charts the numbers outside the circles are the numbers of the labels. To avoid confusion, however, these have been omitted in the case of Experiment 4.

# RE-DESCRIPTION OF A TREMATODE PARASITE, *ALLOCREADIUM LABRACIS* (DUJARDIN), FROM THE BASS.

(Plate III.)

By JAS. JOHNSTONE.

Bass or Sea-Perch (*Labrax* (or *Centropomus*) *lupus*) in the Irish Sea are nearly always infested with a Trematode parasite which is evidently the species *Allocreadium labracis* (Dujardin). This worm, if not of universal occurrence in the fish, is very common, and I have found it in specimens taken in Cardigan Bay, in the Irish Sea, and in Morecambe Bay. The bass is an inhabitant of the Mediterranean and the adjacent Atlantic coastal waters, where it is very abundant. It enters St. George's Channel and the Irish Sea in shoals in the early summer, and in June has reached Morecambe Bay, where there is nearly always a fishery for it during June, July and August. About September or October the shoals disappear. The fish appears to be largely a fish-eater, feeding upon young sand-eels and sprats which are abundant in Morecambe Bay during these months. Although common in the English Channel and the Irish Sea area, the shoals do not migrate much further north, and only isolated specimens are taken on the East Coast of Scotland, north of the Forth, and in Scandinavian waters. The parasite *Allocreadium labracis* appears to be a good example of a Trematode which has only one final host, as all the descriptions in the literature appear to relate to worms taken from the intestine of the bass. Thus Dujardin's original description of the species was based on a specimen taken from *Labrax lupus*, and Stossich and Molin described it from the same host.* In such cases as this the occurrence of a

* The literature is summarised by Odhner in *Zool. Jahrb. Abth. System.*, Bd. 14, 1900-1. I am indebted to Mr. W. Nicol, of the Gatty Marine Laboratory, for directing my attention to this paper, and for other assistance.

parasite is often a useful indication of the places of origin of fishes with periodic migratory habits.

The following description of the trematode may be useful, since the species is not at all fully described in the literature. It is based on a reconstruction from a complete series of sections made from a worm of 9·7 mm. in total length, the largest found. The trematode was killed by immersion in fresh water, and was subsequently preserved in formalin, a procedure which enables one to preserve the worm with the minimum amount of distortion. But such a method is not favourable for the study of histological details, and I deal here only with the coarser anatomy of the parasite.

The measurements of the specimen are:—

Total length: 9·7 mm.

Greatest breadth: 2 mm.

Transverse diameter of oral sucker: 0·76 mm.

„ „ ventral sucker: 0·94 mm.

Diameters of ova: 0·079—0·095 by 0·048—0·064 mm.

Transverse diameter of oral sucker is contained 12 times in total body length.

Transverse diameter of ventral sucker is contained $9\frac{1}{2}$ times in total body length.

Odhner's measurements vary slightly from those given above. Thus in his fig. 11, Taf. 33 (*op. cit.*) the body length is $10\frac{1}{2}$ times the transverse diameter of the oral sucker, and $6\frac{1}{2}$ times the transverse diameter of the ventral sucker. These ratios are not of precise diagnostic value; thus in a smaller specimen examined I found that the diameter of the oral sucker was contained about 10 times in the body length, and that of the ventral sucker about 7 times. Neither are the diameters of the ova very constant. Odhner gives these as 0·07—0·08 by 0·037.

The **body** is nearly cylindrical, and is only flattened dorso-ventrally at about the middle of the length. It is, as a rule, nearly uniform in diameter only tapering gently at either extremity. The skin possesses no spines or other form of armature.

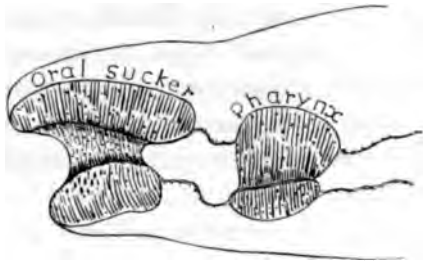



FIG. 1. *Allocreadium labracis* (Duj.). Median longitudinal section through mouth and pharynx.

The **mouth** is subterminal, as is indicated in fig. 1, which represents part of a median longitudinal section. Immediately following the oral sucker, and connected to it by a delicate tube is a strongly muscular, nearly globular **pharynx** of the usual type. The lumen of the pharynx is a longitudinal dorso-ventral slit, the inner surfaces of which are hard and fibrous. The pharynx passes immediately into a rather short oesophagus which, almost at once, bifurcates to form the two intestinal rami. The two branches of the intestine run roughly parallel to each other to almost the posterior extremity of the body. They have a nearly uniform diameter throughout. The lumen is not a simple one throughout. Round the periphery the wall is produced axially into the lumen as a loose vacuolated tissue, the central vacuoles being larger and continuous with each other, and this is the case as far back as the middle of the body. From thence backwards the vacuolated tissue in the intestine becomes

looser and finally disappears. The intestine is then a simple, thin-walled tube.

There is a very distinct **intestinal musculature.** From the posterior wall of the pharynx a series of strong muscle bundles take origin and pass backwards slightly obliquely to be inserted into the walls of the oesophagus just behind the pharynx. From here to the extremity of the intestinal branches these longitudinal muscles persist. They always appear in transverse sections of the body as little protuberances on the external surface of the intestine. They do not, however, form very long bundles, but are attached at intervals to the surface of the gut forming a series of short loops. They run quite longitudinally, and not at all obliquely. It is these longitudinal muscles which produce the peristaltic movements of the intestine. Circular muscle fibres are not to be seen in section, and are probably absent. But here and there the gut is attached to the lateral walls of the body by fibrous bundles, many of which appear to be muscular, and the contractions of these extrinsic intestinal muscles are probably antagonistic to those of the intrinsic longitudinal system.

The **ventral sucker** is situated rather nearer to the anterior, than to the posterior extremity. It is not quite round in shape; the longitudinal diameter is the larger in my specimens. The shape of the opening is, of course, variable, but is usually triangular. This sucker possesses a strong extrinsic musculature. All round its ventral periphery strong bundles of muscular and connective tissue take origin and run out radially to be inserted into the lateral and ventral body walls. Some run dorso-ventrally and are inserted into the dorsal body walls. These muscles, originating in the periphery of the ventral sucker, appear to constitute the principal system of

muscles in the body. There are also muscles which run dorso-ventrally, connecting together the dorsal and ventral body walls, and there are probably some longitudinally arranged muscles, though these latter are not very evident. When the animal dies the ventral sucker usually forms a prominent projection on the ventral surface, and the extremities are bent dorsally. This is probably due to the relaxation of the system of muscles surrounding the sucker, and to a contraction of longitudinal connective tissue fibres in the dorsal body wall.

The **genital aperture** is situated on the ventral surface in the middle line, and immediately behind the bifurcation of the intestine. It is not very evident in cleared preparations and can be recognised usually by the protruded cirrus. (Fig. 2.)

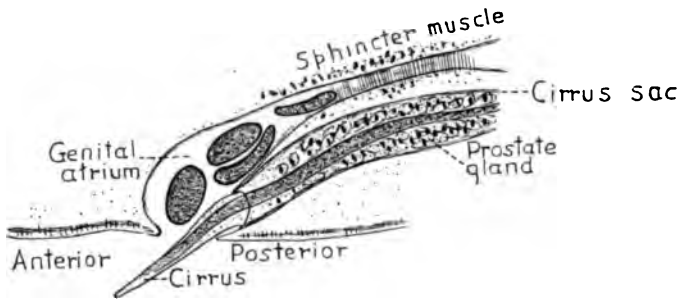



Fig. 2. *Allocreadium labracis* (Duj.). Part of median longitudinal section through genital cloaca.

**The Male Organs** (Fig. 3).

There are two **testes,** nearly spherical in shape, but with rather irregular outlines, and nearly equal in size. They are situated nearly midway between the ventral sucker and the posterior extremity of the body. They lie one behind the other in the middle line. A **vas efferens** takes origin from each, one vessel from the

antero-dorsal surface of the posterior testis, and the other from the dorsal surface of the anterior organ. They run forward, pursuing an undulating course, penetrating between the convolutions of the uterus, and then dorsal to the ventral sucker. At the posterior margin of the latter they join together, entering at once into a capacious **seminal vesicle.**

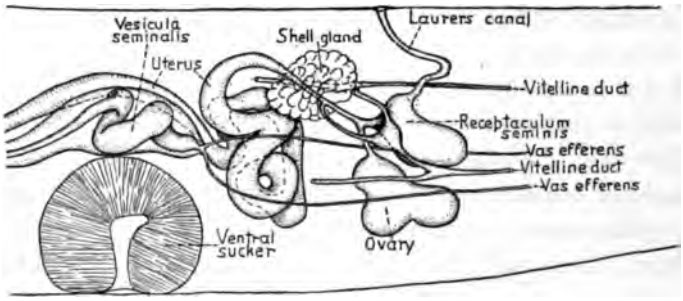



Fig. 3. *Allocreadium labracis* (Duj.). Diagram of genital ducts. Projection in vertical horizontal plane.

This latter structure is a wide tube situated dorsally to the ventral sucker. It is either a straight, or slightly bent vessel, as is shewn in fig. 3, or is thrown into two or three loose coils, as is indicated in Plate III, which is a projection in a longitudinal plane of the genital organs, and has been deduced from a series of longitudinal sections. The seminal vesicle is surrounded by a fairly thick fibrous and muscular sheath—the **cirrus-sheath.** At about the anterior margin of the ventral sucker the seminal vesicle contracts greatly in diameter to form the cirrus. But the cirrus-sheath is still wide, and the space between cirrus and sheath contains the follicles of the **prostate gland.** The cirrus itself is a narrow, thick-walled tube, and it is quite unarmed. The cirrus-sheath or pouch terminates in the ventral and posterior part of

the genital cloaca, and in preserved specimens the cirrus usually protrudes from the opening of the former.

**The Female Organs** (Pl. III and fig. 3).

The **ovary** is rather small, and is situated on the right side between the ventral sucker and anterior testis. It is trilobate in shape in the published descriptions of the species, but in my specimens there are always three equal-sized, rounded lobes in a horizontal plane, and dorsal to these, and nearly over the anterior lobe, another from which a short, thin duct takes origin. Immediately dorsal to the ovary, and usually obscured by the latter in cleared preparations, is a capacious **receptaculum seminis.** The little duct leaving the ovary joins the former at its anterior border. There is a projection of the receptaculum seminis on its dorsal and anterior part, and from this a fairly wide and thick-walled duct—**Laurer's canal** —takes origin, runs at first backward and upward forming a prominent bend, and then passes obliquely forward to open on the dorsal surface of the body and nearly in the middle line. Laurer's canal was empty in my specimens. The receptaculum seminis contained granular matter, the nature of which could not be determined: it was probably broken down spermatozoa.

Just where the duct from the ovary joins the receptaculum seminis the **ootype** takes origin. This is a very narrow tube which runs at first directly forward, through a mass of loose gland follicles, which together form the **shell-gland.** Emerging from the latter (which, of course, opens into it) the ootype enlarges greatly to form the **uterus,** and the latter is thrown into a series of close convolutions filling up most of the space between ovary and receptaculum seminis behind, and ventral sucker forward. The uterus is not nearly so capacious as in many other trematodes. Its general appearance and

distribution is represented in Pl. III. In fig. 3 the convolutions are represented diagrammatically to secure clearness. For the same reason the eggs have been omitted in both figures. The uterus passes forward over the ventral sucker, at first side by side, and then dorsal to, the seminal vesicle. It contracts greatly in diameter in the neighbourhood of the latter structure. Here, and here only, the uterus is muscular. Just over the prostate gland there is a sphincter muscle (fig. 2), the contraction of which usually reduces the calibre of the uterus to much less than the diameter of an ovum. In fig. 2 this sphincter is represented as a long-drawn-out structure, but in other sections I have seen it as a short, thick, flat ring of muscle fibres. This indicates that there are probably also longitudinal muscle fibres present, though it is difficult to see these. The structure functions doubtless in the extrusion of the ova.

Immediately in front of this sphincter muscle the calibre of the uterus enlarges, and we have a fairly wide chamber which is the genital cloaca (fig. 2). In this, as the figure shows, there are usually a few eggs. The opening on the surface of the body is circular. Into the terminal part of the genital cloaca there opens the cirrus pouch, and usually the cirrus itself protrudes from the latter, and out from the genital aperture on to the surface of the body.

The **vitellaria** are very characteristic. In a cleared preparation they appear to ramify over every part of the body, obscuring most of the other organs. This is particularly the case at the posterior extremity, where the vitelline glands appear to fill up the whole body. But in section they are seen to be arranged peripherally, generally as a single stratum of gland follicles. At the middle of the body they are dorsal and lateral. In front

of the ventral sucker they are present only beneath the dorsal body wall. In the region of the testes they are lateral (fig. 4) and do not appear on dorsal and ventral surfaces. Behind the testes they are distributed round the entire periphery of the body. They are very numerous, and when the worm is contracted greatly appear very closely packed together, so that it is almost impossible to make out the other organs. Indeed it is only by killing the trematode in fresh water, and then by flattening it out between two microscope slides during fixation, that the animal can be preserved in a condition fit for staining and clearing.

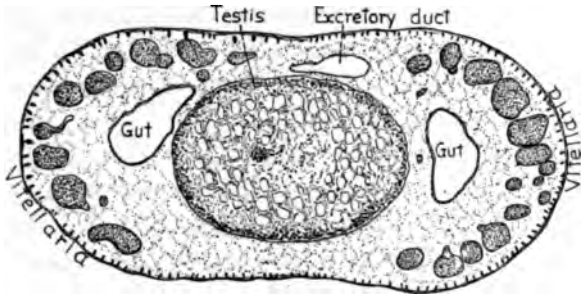
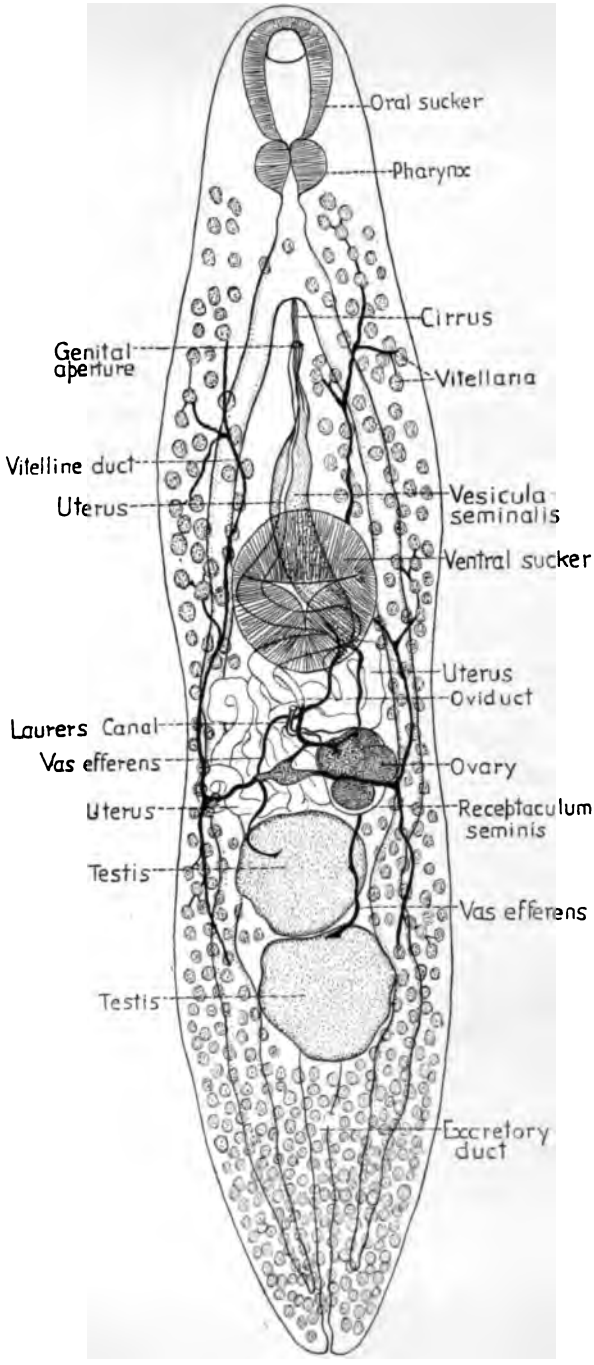



Fig. 4. *Allocreadium labracis* (Duj.). Transverse section through posterior testis.

**The vitelline ducts** have the usual disposition. It is not difficult to trace most of their ramifications in a successful preparation. One main longitudinal duct runs along either side of the body, and to this numerous ductules proceed from the follicles of the gland. At about the transverse level of the ovary fairly wide transverse ducts appear, and these run across towards the middle line, uniting to form a rather large vesicle, which is, of course, only an enlargement of the united ducts. From this vesicle a slender efferent duct takes origin, and runs




*Allocreadium labracis* (Dujardin). Dorsal aspect.
Reconstructed from serial sections mag. = ×18.

obliquely forward to pass into the midst of the follicles of the shell gland. It is difficult to trace in section, but can be seen to open into the ootype as the latter passes through the shell-gland.

**The excretory system** cannot be traced in sections. There is one main vessel which opens to the surface at the very posterior tip of the body. It is elongated dorso-ventrally. It can easily be traced in section as far forward as the testes, and here it is lost. Doubtless it breaks up in the characteristic manner into a multitude of smaller vessels, but I could see no indication of the usual two lateral excretory vessels uniting in the region of the oral sucker. But it is always much easier to trace the excretory system in the living worm, and I had no opportunity of examining such specimens.

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## Plate III.

*Allocreadium labracis* (Dujardin).

Reconstructed from a series of transverse sections. Magnified about 18 diameters.

# REPORT ON THE HYDROGRAPHIC WORK IN THE EASTERN PORTION OF THE IRISH SEA BETWEEN JULY, 1906, AND NOVEMBER, 1907.

By Henry Bassett, Jun., B.Sc., Ph.D., Demonstrator and Assistant Lecturer in Chemistry in the University of Liverpool.

The seas surrounding the British Isles are filled with only slightly diluted Atlantic water.

Speaking generally, the water filling the Irish Sea is a good deal more dilute than that in the English Channel and the North Sea, and, owing to the tidal current which runs from South to North through the Irish Sea and round the North Coast of Scotland, the water from the Irish Sea plays a very important part in the dilution of the Atlantic water which goes to fill the North Sea.

The Irish Sea is plainly so dilute because of the large volumes of fresh water flowing into it from the land.

Now a very large proportion indeed of the fresh water running into the Irish Sea runs into that portion of it which is situated to the East of a line drawn from Burrow Head, in Wigtownshire, due South to Anglesey; for most of the drainage from the parts of England and North Wales having the largest rainfall passes into this portion. This part of the Irish Sea is also remarkable for its strong tides, and these, owing to the peculiar conformation of the coast line, and the position of the Isle of Man, cause a very thorough mixing of the waters, and ensure the efficient dilution of any salter water coming in from the South.

A study of the salinity of this portion of the Irish Sea promised, therefore, to be of considerable interest.

For some years past temperature and salinity measurements at various depths have been made in the Western portion of the Irish Sea by the Irish Board of Agriculture and Technical Instruction, under the direction of Mr. E. W. L. Holt; but up to 1906 the Eastern portion had been left almost entirely alone. From 1904 onwards the "Bulletins trimestriels du Conseil permanent international pour l'exploration de la mer" give the results of salinity and temperature observations made on surface samples collected by the Bahama Bank (54° 19′ N; 40° 13′ E) and Cardigan Bay (52° 24′ N; 5° 00′ E) lightships. From this information surface isohalines are drawn in the published charts.

In July, 1906, a systematic study of the Eastern portion of the Irish Sea was begun under the scheme of hydrographic observations sanctioned by the Lancashire and Western Sea-Fisheries Committee. On the first voyage samples were collected from points situated on lines drawn from Piel Gas Buoy to Maughold Head, and from the Calf of Man to Holyhead breakwater. A few samples from other positions were also collected on this trip. These two lines were kept to until the end of 1906, during which interval of time two more trips were made.

For the next two trips (February and May, 1907) the first line of soundings was altered to one running W.N.W. from Piel Gas Buoy instead of N.W. The other line remained as before.

Finally, in July, 1907, the first line underwent a slight alteration so as to make it run along the 54° of latitude and to bring it into agreement with the line of soundings run out from the Irish Coast to the Calf of

Man by Mr. Holt. The line from the Calf of Man to Holyhead still remained as before.

In May, 1907, the area under investigation was extended somewhat, an additional line of soundings being run across Carnarvon and Cardigan Bays.

The water samples, except those from the surface, have always been collected by means of a Nansen-Pettersson water-bottle, while the temperatures have been taken with the usual pattern of thermometer used in the International Fishery Investigations. The titrations of the water samples have been carried out in the usual way by Mohr's method,* and the salinities, etc. calculated by means of Knudsen's Hydrographic tables. The titrations have all been done by myself, but I have only occasionally been able to go out on the steamer collecting the samples. The latter have usually been obtained by my colleague, Mr. James Johnstone, whom I have much pleasure in thanking for this and much other assistance.

My thanks are also due to Captain A. Wignall, of the "John Fell," the steamer of the Lancashire and Western Sea-Fisheries Committee, from which all the observations have been made, for the skill with which he has fixed the positions of the soundings.

The salinites and other details for the various stations are given in the following tables. The first column gives the depth in metres; T° is the temperature (Centigrade) of the water *in situ*; Cl $‰$ is the amount of chlorine per 1000 parts of water as found by the titration; S $‰$ is the salinity; and $1 + \frac{\sigma_t}{1000}$ gives the density of the sample of water at the temperature T°. The position of the station and the date on which the samples were collected are given above each table.

*For details of the method as applied to hydrographic work, see Niels Bjerrum, Meddelelser fra Kommissionen for Havundersogelser. Serie Hydrografi. Vol. I, No. 3.—Copenhagen, 1904.

July 2 to 5, 1906.

The positions on the two chief lines are given first.

5/7/06. 54° 4′ N.; 3° 23′ W. Depth of station, 22 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 14·15 | 18·18 | 32·84 | 24·52 |
| 9·2 | 13·5 | 18·16 | 32·81 | 24·64 |
| 18·3 | 13·5 | 18·16 | 32·81 | 24·64 |

5/7/06. 54° 7′ N.; 3° 37′ W. Depth of station, 30·2 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·96 | 18·14 | 32·77 | 24·08 |
| 9·2 | 13·5 | 18·15 | 32·79 | 24·62 |
| 18·3 | 12·2 | 18·36 | 33·17 | 25·14 |
| 27·5 | 11·9 | 18·39 | 33·22 | 25·26 |

5/7/06. 54° 11′ N.; 3° 51′ W. Depth of station, 27·5 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·55 | 18·14 | 32·77 | 24·18 |
| 9·2 | 12·80 | 18·29 | 33·04 | 24·95 |
| 18·3 | 12·30 | 18·46 | 33·35 | 25·28 |
| 25·6 | 12·25 | 18·46 | 33·35 | 25·29 |

5/7/06. 54° 14′ N.; 4° 3′ W. Depth of station, 27·5 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 14·6 | 18·44 | 33·31 | 24·77 |
| 9 2 | 12·6 | 18·52 | 33·46 | 25·28 |
| 23·8 | 12·3 | 18·54 | 33·49 | 25·38 |

3/7/06. 53° 55′ N.; 4° 56′ W. Depth of station, 76·9 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·46 | 18·93 | 34·24 | 25·89 |
| 9·2 | 12·15 | 18·90 | 34·14 | 25·90 |
| 18·3 | 12·15 | 18·92 | 34·18 | 25·93 |
| 36·6 | 11·45 | 18·92 | 34·18 | 26·07 |
| 54·9 | 9·97 | 18·94 | 34·22 | 26·36 |
| 73·2 | 9·55 | 18·94 | 34·22 | 26·42 |

3/7/06. 53° 49′ N.; 4° 46′ W. Depth of station, 58·1 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·19 | 18·91 | 34·16 | 26·10 |
| 9·2 | 11·02 | 18·90 | 34·14 | 26·14 |
| 18·3 | 11·02 | 18·90 | 34·14 | 26·14 |
| 36·6 | 11·00 | 18·91 | 34·16 | 26·15 |
| 51·3 | 11·00 | 18·90 | 34·14 | 26·14 |

3/7/06. 53° 37′ N.; 4° 42′ W. Depth of station, 54·9 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·72 | 18·89 | 34·13 | 25·97 |
| 9·2 | 11·00 | 18·90 | 34·14 | 26·14 |
| 18·3 | 11·00 | 18·89 | 34·13 | 26·12 |
| 36·6 | 11·00 | 18·90 | 34·14 | 26·14 |
| 54·9 | 11·00 | 18·90 | 34·14 | 26·14 |

3/7/06. 53° 29′ N.; 4° 40′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·80 | 18·85 | 34·05 | 25·90 |
| 9·2 | 11·62 | 18·82 | 34·00 | 25·88 |
| 18·3 | 11·60 | 18·82 | 34·00 | 25·88 |
| 36·6 | 11·60 | 18·83 | 34·02 | 25·90 |
| 54·9 | 11·55 | 18·86 | 34·07 | 25·94 |

3/7/06. 53° 24′ N.; 4° 39′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·65 | 18·87 | 34·09 | 25·95 |

Samples were only collected from the following stations on this one trip.

2/7/06. 53° 26′ N.; 4° 26′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 27·5 | 12·20 | 18·75 | 33·87 | 25·70 |

3/7/06. 54° 22′ N.; 4° 34′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·10 | 18·89 | 34·13 | 25·90 |

3/7/06. 54° 25′ N.; 4° 21′ W. Depth of station, 23·8 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·45 | 18·78 | 33·93 | 25·68 |
| 9·2 | 12·00 | 18·78 | 33·93 | 25·78 |
| 18·3 | 12·00 | 18·76 | 33·89 | 25·75 |

3/7/06. 54° 22′ N.; 4° 19′ W. Depth of station, 31·1 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·95 | 18·58 | 33·57 | 25·31 |
| 9·2 | 12·30 | 18·56 | 33·53 | 25·41 |
| 18·3 | 12·23 | 18·57 | 33·55 | 25·44 |
| 27·5 | 12·23 | 18·58 | 33·57 | 25·45 |

3/7/06. 54° 22′ N.; 4° 2′ W. Depth of station, 40·3 metres.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 14·1 | 18·29 | 33·04 | 24·69 |
| 9·2 | 12·70 | 18·31 | 33·08 | 24·98 |
| 18·3 | 12·60 | 18·32 | 33·10 | 25·01 |
| 36·6 | 11·35 | 18·46 | 33·35 | 25·45 |

5/7/06. 54° 0′ N.; 3° 13′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 17·00 | 17·53 | 31·67 | 23·00 |

5/7/06. 54° 3′ N.; 3° 10′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·90 | 18·09 | 32·68 | 24·01 |

5/7/06. 53° 58′ N.; 3° 9′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 16·00 | 17·64 | 31·87 | 23·37 |

Surface samples collected on July 9 and 10, 1906.

| Position. | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 53° 19′ N. ; 4° 43′ W. | 12·9 | 18·88 | 34·11 | 25·75 |
| 53° 10′ N. ; 4° 43′ W. | 12·2 | 18·95 | 34·23 | 25·98 |
| 53° 1′ N. ; 4° 44′ W. | 11·4 | 19·03 | 34·38 | 26·25 |
| 52° 52′ N. ; 4° 45′ W. | 11·9 | 19·02 | 34·36 | 26·14 |
| 52° 47′ N. ; 4° 43′ W. | 12·9 | 18·89 | 34·13 | 25·76 |
| 52° 26′ N. ; 4° 34′ W. | 13·5 | 18·86 | 34·07 | 25·61 |
| 52° 18′ N. ; 4° 27′ W. | 14·8 | 18·82 | 34·00 | 25·27 |
| 52° 13′ N. ; 4° 24′ W. | 15·0 | 18·69 | 33·77 | 25·04 |

September 18 and September 19, 1906.

18/9/06. 54° 3′ N. ; 3° 22′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·20 | 18·25 | 32·97 | 24·40 |
| 9·2 | 13·50 | 18·26 | 32·99 | 24·77 |
| 22·0 | 13·50 | 18·24 | 32·95 | 24·74 |

18/9/06. 54° 7′ N. ; 3° 36′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·00 | 18·38 | 33·21 | 24·63 |
| 9·2 | 14·00 | 18·37 | 33·19 | 24·83 |
| 18·3 | 14·00 | 18·51 | 33·44 | 25·02 |
| 27·5 | 14·00 | 18·53 | 33·48 | 25·04 |

18/9/06. 54° 10′ N. ; 3° 50′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·2 | 18·44 | 33·31 | 24·67 |
| 9·2 | 14·0 | 18·46 | 33·35 | 24·94 |
| 18·3 | 14·0 | 18·47 | 33·37 | 24·95 |
| 27·5 | 14·0 | 18·47 | 33·37 | 24·95 |

18/9/06. 54° 14′ N.; 4° 2′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·0 | 18·52 | 33·46 | 24·81 |
| 9·2 | 14·0 | 18·52 | 33·46 | 25·01 |
| 18·3 | 14·0 | 18·52 | 33·46 | 25·01 |
| 27·5 | 14·0 | 18·52 | 33·46 | 25·01 |

19/9/06. 53° 56′ N.; 4° 47′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·7 | 18·84 | 34·04 | 25·54 |
| 9·2 | 13·0 | 18·85 | 34·05 | 25·68 |
| 18·3 | 13·0 | 18·84 | 34·04 | 25·67 |
| 36·6 | 13·0 | 18·84 | 34·04 | 25·67 |
| 53·1 | 13·0 | 18·84 | 34·04 | 25·67 |

19/9/06. 53° 47′ N.; 4° 45′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·7 | 18·89 | 34·13 | 25·60 |
| 9·2 | 13·5 | 18·88 | 34·11 | 25·63 |
| 18·3 | 13·2 | 18·88 | 34·11 | 25·69 |
| 36·6 | 13·2 | 18·88 | 34·11 | 25·69 |
| 58·6 | 13·2 | 18·88 | 34·11 | 25·69 |

19/9/06. 53° 38′ N.; 4° 43′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·8 | 18·89 | 34·13 | 25·60 |
| 18·3 | 13·5 | 18·90 | 34·14 | 25·66 |
| 36·6 | 13·5 | 18·88 | 34·11 | 25·63 |
| 54·9 | 13·5 | 18·89 | 34·13 | 25·65 |
| 69·5 | 13·2 | 18·88 | 34·11 | 25·69 |

19/9/06. 53° 28′ N.; 4° 40′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 14·7 | 18·84 | 34·04 | 25·34 |
| 9·2 | 13·8 | 18·82 | 34·00 | 25·49 |
| 18·3 | 13·8 | 18·84 | 34·04 | 25·54 |
| 36·6 | 13·5 | 18·83 | 34·02 | 25·57 |
| 64·1 | 13·5 | 18·83 | 34·02 | 25·57 |

November 13—November 14, 1906.

13/11/06. 54° 3′ N.; 3° 22′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·0 | 18·49 | 33·40 | 25·56 |
| 9·2 | 11·0 | 18·49 | 33·40 | 25·56 |
| 25·7 | 11·0 | 18·49 | 33·40 | 25·56 |

13/11/06. 54° 7′ N.; 3° 36′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·1 | 18·62 | 33·64 | 25·72 |
| 9·2 | 11·3 | 18·62 | 33·64 | 25·68 |
| 27·5 | 11·3 | 18·65 | 33·69 | 25·72 |

13/11/06. 54° 10′ N.; 3° 50′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·1 | 18·30 | 33·06 | 25·27 |
| 9·2 | 10·7 | 18·28 | 33·03 | 25·30 |
| 26·5 | 10·7 | 18·29 | 33·04 | 25·31 |

13/11/06. 54° 14′ N.; 4° 2′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 10·6 | 18·29 | 33·04 | 25·33 |
| 9·2 | 10·6 | 18·30 | 33·06 | 25·34 |
| 22·0 | 10·6 | 18·25 | 32·97 | 25·27 |

14/11/06. 53° 56′ N.; 4° 47′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·3 | 18·78 | 33·93 | 25·90 |
| 9·2 | 11·1 | 18·74 | 33·86 | 25·88 |
| 27·5 | 11·1 | 18·75 | 33·87 | 25·90 |
| 45·8 | 11·1 | 18·75 | 33·87 | 25·90 |

14/11/06. 53° 47′ N.; 4° 45′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·8 | 18·83 | 34·02 | 25·89 |
| 9·2 | 11·6 | 18·84 | 34·04 | 25·93 |
| 36·6 | 11·6 | 18·82 | 34·00 | 25·90 |
| 64·1 | 11·6 | 18·82 | 34·00 | 25·90 |

14/11/06. 53° 38′ N.; 4° 43′ W.

| Depth (metres) | T° | Cl °/∞ | S °/∞ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·0 | 18·84 | 34·04 | 25·86 |
| 9·2 | 11·9 | 18·83 | 34·02 | 25·87 |
| 45·8 | 12·0 | 18·84 | 34·04 | 25·86 |

February 13—February 18, 1907.

13/2/07 (10-40 a.m.) 54° 1′ N.; 3° 30′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 3·6 | 17·88 | 32·30 | 25·71 |
| 18·3 | 3·5 | 17·89 | 32·32 | 25·74 |
| 27·5 | 3·5 | 17·89 | 32·32 | 25·74 |

13/2/07 (11-50 a.m.) 54° 2′ N.; 3° 47′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 4·6 | 18·22 | 32·92 | 26·08 |
| 18·3 | 3·4 | 18·21 | 32·90 | 26·19 |
| 36·6 | 3·5 | 18·22 | 32·92 | 26·19 |

13/2/07 (1-0 p.m.) 54° 2′ N.; 4° 4′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 5·9 | 18·40 | 33·24 | 26·22 |
| 18·3 | 5·3 | 18·37 | 33·19 | 26·23 |
| 27·5 | 5·3 | 18·38 | 33·21 | 26·24 |

13/2/07 (2-10 p.m.) 54° 3′ N.; 4° 20′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 5·65 | 18·54 | 33·49 | 26·44 |
| 18·3 | 5·6 | 18·54 | 33·49 | 26·44 |
| 34·8 | 5·6 | 18·53 | 33·48 | 26·43 |

18/2/07 (1-0 p.m.) 53° 53′ N.; 4° 46′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 7·3 | 19·04 | 34·40 | 26·93 |
| 18·3 | 6·9 | 19·03 | 34·38 | 26·97 |
| 36·6 | 6·9 | 19·03 | 34·38 | 26·97 |
| 54·9 | 6·9 | 19·03 | 34·38 | 26·97 |

18/2/07 (11-55 a.m.) 53° 43′ N.; 4° 44′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 7·2 | 19·00 | 34·33 | 26·89 |
| 18·3 | 6·9 | 18·98 | 34·29 | 26·90 |
| 36·6 | 6·9 | 18·99 | 34·31 | 26·92 |
| 54·9 | 6·9 | 18·99 | 34·31 | 26·92 |

18/2/07 (10-45 a.m.) 53° 33′ N.; 4° 41′ W.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 6·7 | 18·68 | 33·75 | 26·49 |
| 18·3 | 6·5 | 18·69 | 33·77 | 26·54 |
| 36·6 | 6·5 | 18·69 | 33·77 | 26·54 |
| 54·9 | 6·5 | 18·72 | 33·82 | 26·59 |

**May 6—May 8, 1907.**

6/5/07 (8-50 a.m.) 54° 1′ N.; 3° 31′ W. Depth of station, 28 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 7·95 | 18·02 | 32·56 | 25·39 |
| 9·2 | 7·8 | 18·03 | 32·57 | 25·43 |
| 18·3 | 7·7 | 18·07 | 32·65 | 25·49 |
| 27·5 | 7·65 | 18·19 | 32·86 | 25·66 |

6/5/07 (10 a.m.) 54° 2′ N.; 3° 47′ W. Depth of station, 40·3 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·2 | 18·50 | 33·42 | 26·03 |
| 9·2 | 7·75 | 18·48 | 33·39 | 26·07 |
| 18·3 | 7·7 | 18·50 | 33·42 | 26·10 |
| 36·6 | 7·8 | 18·57 | 33·55 | 26·20 |

6/5/07 (11 a.m.) 54° 2′ N.; 4° 4′ W. Depth of station, 38·5 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·4 | 18·63 | 33·66 | 26·18 |
| 9·2 | 7·75 | 18·64 | 33·68 | 26·30 |
| 18·3 | 7·8 | 18·63 | 33·66 | 26·28 |
| 36·6 | 7·7 | 18·68 | 33·75 | 26·36 |

6/5/07 (noon). 54° 3′ N.; 4° 20′ W. Depth of station, 42·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·1 | 18·96 | 34·25 | 26·69 |
| 9·2 | 7·85 | 18·97 | 34·27 | 26·75 |
| 18·3 | 7·85 | 18·97 | 34·27 | 26·75 |
| 36·6 | 7·8 | 18·96 | 34·25 | 26·73 |

7/5/07 (8-40 a.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 7·8 | 19·00 | 34·33 | 26·79 |
| 9·2 | 7·5 | 19·02 | 34·36 | 26·87 |
| 18·3 | 7·6 | 19·04 | 34·40 | 26·90 |
| 36·6 | 7·6 | 19·05 | 34·42 | 26·91 |
| 60·4 | 7·6 | 19·05 | 34·42 | 26·91 |

7/5/07 (10 a.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 7·95 | 18·98 | 34·29 | 26·74 |
| 9·2 | 7·75 | 18·97 | 34·27 | 26·78 |
| 18·3 | 7·75 | 18·99 | 34·31 | 26·81 |
| 36·6 | 7·7 | 18·98 | 34·29 | 26·79 |
| 60·4 | 7·7 | 19·00 | 34·33 | 26·82 |

7/5/07 (11-25 a.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 58·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·1 | 18·80 | 33·96 | 26·45 |
| 9·2 | 8·0 | 18·78 | 33·93 | 26·46 |
| 18·3 | 8·0 | 18·78 | 33·93 | 26·46 |
| 36·6 | 8·0 | 18·79 | 33·95 | 26·48 |
| 54·9 | 8·0 | 18·79 | 33·95 | 26·48 |

7/5/07 (2-25 p.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 58·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·3 | 18·95 | 34·23 | 26·65 |
| 9·2 | 8·1 | 18·95 | 34·23 | 26·69 |
| 18·3 | 7·95 | 18·96 | 34·25 | 26·71 |
| 36·6 | 7·9 | 18·94 | 34·22 | 26·69 |
| 54·9 | 7·9 | 18·94 | 34·22 | 26·69 |

8/5/07 (9-15 a.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 43·9 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·7 | 18·84 | 34·04 | 26·44 |
| 9·2 | 8·4 | 18·84 | 34·04 | 26·49 |
| 18·3 | 8·4 | 18·84 | 34·04 | 26·49 |
| 36·6 | 8·4 | 18·84 | 34·04 | 26·49 |

8/5/07 (10-30 a.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 40·3 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 8·8 | 18·81 | 33·98 | 26·38 |
| 9·2 | 8·7 | 18·81 | 33·98 | 26·39 |
| 18·3 | 8·65 | 18·81 | 33·98 | 26·39 |
| 36·6 | 8·6 | 18·81 | 33·98 | 26·40 |

July 29—July 30, 1907.

29/7/07 (8-30 a.m.) 54° N.; 3° 30′ W. Depth of station, 27·5 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 15·8 | 17·64 | 31·87 | 23·42 |
| 9·2 | 13·5 | 17·76 | 32·09 | 24·07 |
| 18·3 | 13·0 | 18·11 | 32·72 | 24·66 |
| 27·5 | 13·0 | 18·13 | 32·75 | 24·69 |

29/7/07 (9-50 a.m.) 54° N.; 3° 47′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·0 | 18·67 | 33·73 | 26·43 |
| 9·2 | 12·8 | 18·71 | 33·80 | 26·54 |
| 18·3 | 12·8 | 18·72 | 33·82 | 26·56 |
| 36·6 | 12·8 | 18·71 | 33·80 | 26·54 |

29/7/07 (11-10 a.m.) 54° N.; 4° 4′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·0 | 18·85 | 34·05 | 26·68 |
| 9·2 | 12·5 | 18·85 | 34·05 | 26·78 |
| 18·3 | 12·5 | 18·85 | 34·05 | 26·78 |
| 36·6 | 12·6 | 18·85 | 34·05 | 26·76 |

29/7/07 (12-30 p.m.) 54° N.; 4° 20′ W. Depth of station, 45·8 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·6 | 18·88 | 34·11 | 25·81 |
| 18·3 | 12·3 | 18·88 | 34·11 | 25·87 |
| 36·6 | 12·3 | 18·87 | 34·09 | 25·85 |
| 45·8 | 12·3 | 18·87 | 34·09 | 25·85 |

29/7/07 (3 p.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 73·2 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·3 | 18·89 | 34·13 | 25·88 |
| 18·3 | 12·1 | 18·88 | 34·11 | 25·90 |
| 36·6 | 12·0 | 18·88 | 34·11 | 25·92 |
| 64·1 | 11·9 | 18·87 | 34·09 | 25·92 |

29/7/07 (4-25 p.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 54·9 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·1 | 18·87 | 34·09 | 25·88 |
| 18·3 | 11·9 | 18·87 | 34·09 | 25·92 |
| 36·6 | 11·9 | 18·87 | 34·09 | 25·92 |
| 53·1 | 11·9 | 18·87 | 34·09 | 25·92 |

29/7/07 (5-45 p.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 54·9 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·9 | 18·81 | 33·98 | 25·66 |
| 18·3 | 12·7 | 18·80 | 33·96 | 25·68 |
| 36·6 | 12·7 | 18·80 | 33·96 | 25·68 |
| 53·1 | 12·7 | 18·80 | 33·96 | 25·68 |

29/7/07 (8-45 p.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 13·25 | 18·84 | 34·04 | 25·63 |
| 18·3 | 12·8 | 18·86 | 34·07 | 25·75 |
| 36·6 | 12·5 | 18·87 | 34·09 | 25·82 |
| 54·9 | 12·5 | 18·87 | 34·09 | 25·82 |

30/7/07 (8 a.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/$_{oo}$ | S °/$_{oo}$ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·9 | 18·85 | 34·05 | 25·90 |
| 9·2 | 11·8 | 18·85 | 34·05 | 25·92 |
| 18·3 | 11·6 | 18·86 | 34·07 | 25·98 |
| 36·6 | 11·6 | 18·85 | 34·05 | 25·96 |

30/7/07 (9-25 a.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/$_{oo}$ | S °/$_{oo}$ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 14·0 | 18·78 | 33·93 | 25·38 |
| 9·2 | 13·25 | 18·77 | 33·91 | 25·53 |
| 18·3 | 13·25 | 18·78 | 33·93 | 25·54 |
| 36·6 | 13·25 | 18·78 | 33·93 | 25·54 |

November 4—November 6, 1907.

4/11/07 (11-5 a.m.) 54° N.; 3° 30′ W. Depth of station, 29·3 metres.

| Depth (metres) | T° | Cl °/$_{oo}$ | S °/$_{oo}$ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·5 | 18·32 | 33·10 | 25·23 |
| 9·2 | 11·55 | 18·37 | 33·19 | 25·31 |
| 18·3 | 11·7 | 18·44 | 33·31 | 25·38 |
| 27·5 | 11·7 | 18·45 | 33·33 | 25·39 |

4/11/07 (12-15 p.m.) 54° N.; 3° 47′ W. Depth of station, 39·8 metres.

| Depth (metres) | T° | Cl °/$_{oo}$ | S °/$_{oo}$ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·9 | 18·62 | 33·64 | 25·58 |
| 9·2 | 11·8 | 18·63 | 33·66 | 25·61 |
| 18·3 | 11·8 | 18·63 | 33·66 | 25·61 |
| 36·6 | 11·8 | 18·63 | 33·66 | 25·61 |

4/11/07 (1-24 p.m.) 54° N.; 4° 4′ W. Depth of station, 42·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·8 | 18·75 | 33·87 | 25·78 |
| 9·2 | 11·75 | 18·74 | 33·86 | 25·77 |
| 18·3 | 11·7 | 18·75 | 33·87 | 25·80 |
| 36·6 | 11·8 | 18·75 | 33·87 | 25·78 |

4/11/07 (2-30 p.m.) 54° N.; 4° 20′ W. Depth of station, 46·7 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 11·8 | 18·76 | 33·89 | 25·79 |
| 9·2 | 11·75 | 18·75 | 33·87 | 25·78 |
| 18·3 | 11·75 | 18·75 | 33·87 | 25·78 |
| 40·3 | 11·75 | 18·75 | 33·87 | 25·78 |

5/11/07 (10 a.m.) 53° 53′ N.; 4° 46′ W. Depth of station, 87·8 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·45 | 18·82 | 34·00 | 25·75 |
| 18·3 | 12·6 | 18·82 | 34·00 | 25·73 |
| 36·6 | 12·4 | 18·80 | 33·96 | 25·74 |
| 54·9 | 12·4 | 18·80 | 33·96 | 25·74 |
| 82·4 | 12·4 | 18·82 | 34·00 | 25·77 |

5/11/07 (11-25 a.m.) 53° 43′ N.; 4° 44′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·7 | 18·79 | 33·95 | 25·67 |
| 18·3 | 12·7 | 18·79 | 33·95 | 25·67 |
| 36·6 | 12·6 | 18·79 | 33·95 | 25·69 |
| 54·9 | 12·6 | 18·78 | 33·93 | 25·67 |

5/11/07 (12-35 p.m.) 53° 33′ N.; 4° 41′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·4 | 18·67 | 33·73 | 25·55 |
| 18·3 | 12·3 | 18·67 | 33·73 | 25·57 |
| 36·6 | 12·4 | 18·67 | 33·73 | 25·55 |
| 54·9 | 12·4 | 18·67 | 33·73 | 25·55 |

6/11/07 (11-30 a.m.) 53° 5′ N.; 4° 44′ W. Depth of station, 64·1 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·6 | 19·16 | 34·61 | 26·21 |
| 18·3 | 12·5 | 19·15 | 34·60 | 26·21 |
| 36·6 | 12·5 | 19·15 | 34·60 | 26·21 |
| 50·3 | 12·5 | 19·15 | 34·60 | 26·21 |

6/11/07 (2-30 p.m.) 52° 34′ N.; 4° 45′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12·35 | 18·98 | 34·29 | 26·00 |
| 9·2 | 12·35 | 18·95 | 34·23 | 25·96 |
| 18·3 | 12·35 | 18·96 | 34·25 | 25·97 |
| 36·6 | 12·4 | 18·96 | 34·25 | 25·97 |

6/11/07 (3-50 p.m.) 52° 24′ N.; 4° 43′ W. Depth of station, 36·6 metres.

| Depth (metres) | T° | Cl °/₀₀ | S °/₀₀ | $\sigma_t$ |
|---|---|---|---|---|
| 0 | 12 1 | 18·84 | 34·04 | 25·85 |
| 9·2 | 12·15 | 18·82 | 34·00 | 25·81 |
| 18·3 | 12·3 | 18·84 | 34·04 | 25·81 |
| 34·8 | 12·2 | 18·85 | 34·05 | 25·84 |

A careful consideration of the above tables will show that: —

(1) In the majority of cases the water at any given spot has practically the same salinity from top to bottom. There are, however, some well-marked exceptions to this, the stations affected being in the shallower water north of the 54 parallel of latitude. In these exceptional cases there is a more or less rapid increase in salinity with depth. The probable explanation of this will be discussed presently.

(2) There is a small but unmistakeable seasonal variation in the salinities.

To bring out this second point more clearly the salinities at the chief stations for the various months have been collected in the following table. In most cases the salinities have been given to the first place of decimals, and in the case of those stations in which the water at the surface differed markedly in salinity from that at the bottom both top and bottom salinities have been given.

For the present purpose those positions which are bracketed may be considered as one station.

In so far as one is justified in drawing conclusions from only a year and a-half's work, it would appear that at the first four stations the salinity is at a minimum somewhere about February. The maximum salinity is not so well marked but seems to occur between July and November.

In the case of stations 5 and 6 exactly the reverse holds, the maximum salinity occurring in February and the minimum in November. Station 7 which, like 5 and 6, is on the line Holyhead—Calf of Man, resembles stations 1-4 from the fact that the minimum salinity occurs about February.

This difference in the time of minimum salinity is

| Position | | July 1906 | Sept. 1906 | Nov. 1906 | Feb. 1907 | May 1907 | July 1907 | Nov. 1907 |
|---|---|---|---|---|---|---|---|---|
| ; 3° 30′ W. | 1 | — | — | — | — | — | 31·87<br>32·75 | 33·1<br>33·3 |
| N.; 3° 31′ W. | | — | — | — | 32·3 | 32·56<br>32·86 | — | — |
| N.; 3° 22′ W. | | 32·8 | 33·0 | 33·4 | — | — | — | — |
| ; 3° 47′ W. | 2 | — | — | — | — | — | 33·73<br>33·80 | 33·64<br>33·66 |
| N.; 3° 47′ W. | | — | — | — | 32·92 | 33·42<br>33·55 | — | — |
| N.; 3° 36′ W. | | 32·8<br>33·2 | 33·2<br>33·5 | 33·6 | — | — | — | — |
| ; 4° 4′ W. | 3 | — | — | — | — | — | 34·05 | 33·9 |
| N.; 4° 4′ W. | | — | — | — | 33·2 | 33·7 | — | — |
| ′N.; 3° 50′ W. | | 32·8<br>33·4 | 33·3<br>33·4 | 33·0 | — | — | — | — |
| ; 4° 20′ W. | 4 | — | — | — | — | — | 34·1 | 33·9 |
| N.; 4° 20′ W. | | — | — | — | 33·5 | 34·3 | — | — |
| ′N.; 4° 2′ W. | | 33·3<br>33·5 | 33·46 | 33·0 | — | — | — | — |
| ′N.; 4° 46′ W. | 5 | — | — | — | 34·4 | 34·3<br>34·4 | 34·1 | 34·0 |
| ′N.; 4° 47′ W. | | 34·2 | 34·0 | 33·9 | — | — | — | — |
| ′N.; 4° 44′ W. | 6 | — | — | — | 34·3 | 34·3 | 34·1 | 33·95 |
| ′N.; 4° 45′ W. | | 34·15 | 34·1 | 34·0 | — | — | — | — |
| ′N.; 4° 41′ W. | 7 | — | — | — | 33·8 | 33·95 | 34·0 | 33·7 |
| ′N.; 4° 43′ W. | | 34·1 | 34·1 | 34·0 | — | — | — | — |
| N.; 4° 44′ W. | | — | — | — | — | 34·2 | 34·1 | 34·6 |
| ′N.; 4° 45′ W. | | — | — | — | — | 34·04 | 34·05 | 34·3 |
| ′N.; 4° 43′ W. | | — | — | — | — | 33·98 | 33·9 | 34·0 |

probably due to the way in which the mixing of the fresher and salter water is brought about by the tides, which cause the salter water at stations 5 and 6 to be gradually diluted by the less salt water from further north. This will obviously result in the minimum salinity at stations 5 and 6 roughly corresponding with maximum salinity at the more northerly stations. The different behaviour at station 7 is no doubt due to the fact that at that point the tide running north is much stronger than that running south, so that there is a continuous slight stream from the south.

These last considerations make it clear that in considering the seasonal variation of salinity, the effect of the tides must be borne in mind.

As already mentioned, the portion of the Irish Sea with which the present investigations deal is noted for its strong tides, so it seemed likely that the salinity at any given spot would depend to a slight extent on the state of the tide: as this changed, so the water originally present would be replaced by other water which might well differ in salinity. It was important to see whether any differences so caused were appreciable and likely to mask any seasonal change in the salinity. Samples were accordingly collected from one of the stations every two hours throughout a tidal cycle. The station chosen was that at 54° 2′ N.; 3° 47′ W., as being one at which any such effect would probably be well marked owing to the proximity of the large body of water of low salinity in Morecambe Bay.

The results obtained are given in the following table:

July 2, 1907. 54° 2′ N.; 3° 47′ W. (Sea smooth and weather fine all day.)

| Depth | T° | Cl °/$_{oo}$ | S °/$_{oo}$ | $\sigma_t$ | |
|---|---|---|---|---|---|
| 0 | 11·6 | 18·57 | 33·55 | 25·56 | 6.30 a.m.; 2 h. |
| 9·2 | 11·4 | 18·56 | 33·53 | 25·56 | 20 min. after |
| 44·7 (bottom) | 11·4 | 18·62 | 33·64 | 25·67 | High Water. |
| 0 | 12·0 | 18·60 | 33·60 | 25·53 | 8.30 a.m.; 4 h. |
| 9·2 | 11·5 | 18·57 | 33·55 | 25·58 | 20 min. after |
| 40·3 (bottom) | 11·4 | 18·63 | 33·66 | 25·68 | High Water. |
| 0 | 12·1 | 18·57 | 33·55 | 25·47 | 10.30 a.m.; |
| 9·2 | 11·45 | 18·63 | 33·66 | 25·66 | Low Water. |
| 40·3 (bottom) | 11·3 | 18·64 | 33·68 | 25·71 | |
| 0 | 12·05 | 18·46 | 33·35 | 25·34 | 12.30 p.m.; 4 |
| 9·2 | 11·4 | 18·62 | 33·64 | 25·66 | hrs. before |
| 40·3 (bottom) | 11·2 | 18·65 | 33·69 | 25·74 | High Water. |
| 0 | 12·4 | 18·58 | 33·57 | 25·42 | 2.30 p.m.; 2 |
| 9·2 | 11·55 | 18·58 | 33·57 | 25·50 | hrs. before |
| 40·3 (bottom) | 11·2 | 18·67 | 33·73 | 25·77 | High Water. |
| 0 | 12·1 | 18·59 | 33·58 | 25·50 | 4.30 p.m.; |
| 9·2 | 11·6 | 18·61 | 33·62 | 25·62 | High Water. |
| 40·3 (bottom) | 11·2 | 18·66 | 33·71 | 25·76 | |

It is clear from the above that at any rate at some stations a variation in salinity due to the tide alone does occur. The variation, as was to be expected, is greatest for the surface water and least for the ground water:— The maximum variation at the surface in the above experiment was 0·23; at 9·2 metres it was 0·13 and at the bottom only 0·09.

Now the maximum change of salinity for the same station between February and November, 1907, was 0·81 for the surface and 0·88 for the bottom water. There can be no doubt, therefore, that a small seasonal change in

the salinities occurs, as had already been concluded from the results summarised in the last table but one.

The change due to the tide will certainly, in most cases, be much smaller than that found above. On the line Holyhead—Calf of Man it will probably be undetectable, and on the line Piel Gas Buoy—Calf of Man will probably be greater the nearer the point considered is to the English coast.

Nothing has as yet been said of the temperatures of the water samples. These, of course, are higher in the summer than in the winter. The surface water is in many cases somewhat warmer than the underlying, but in other cases it is the same. From 9·2 metres downwards the temperature is fairly constant. In the case of one or two of the deeper stations there is sometimes a notable diminution in the temperature with depth, and in the case of some of the shallower stations the temperatures are rather irregular. In the shallower water this is probably connected with tidal currents.

A few words may finally be said about the position of certain isohaline lines in this area. That for salinity 34 probably starts at Burrow Head, Wigtownshire, runs across to a point a little west of the Point of Ayre, starts again at the Calf of Man and runs across to Holyhead. It then crosses Carnarvon Bay, making a slight curve inwards, and then goes in almost a straight line across Cardigan Bay, ending near Cardigan. This may be regarded as a sort of mean position about which it will vary with the season, so that, for instance, the portion between the Calf of Man and Holyhead will sometimes (about May) make a considerable bend to the east. The salinity of all the water to the east of this line will be below 34. The 33 isohaline is clearly much more affected by seasonal

changes, but the details available are not sufficient to justify speculations as to its course.

The seasonal variations of salinity found in the area with which this paper deals are probably entirely due to variations in rainfall and in the amount of fresh water flowing into the sea from the land.

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# AN EXAMINATION OF THE OBSERVATIONS MADE ON THE BLACKPOOL CLOSED GROUND DURING THE PERIOD 1892 TO 1906.

(Plate IV.)

By H. J. Buchanan Wollaston.

The statistics for the Closed Ground off Blackpool deal with 327 hauls made with shrimp-trawl, shank-net, and fish-trawl. Table I. is an analysis of the hauls. In three years, 1899, 1901, and 1902, no hauls were taken with the shank-net. As our aim is to form some idea of the variation in the number of young fish from month to month, or year to year, it is obviously of little value to consider the catches of the fish trawls, which have large meshes and are constructed to avoid as much as possible the capture of young fish. We have to resort then to hauls taken with the shrimp-trawl and shank-net for results.

The numbers of hauls were found to be quite insufficient to give useful results if taken monthly. They have, therefore, been taken in seasons of three months each, viz., January to March, April to June, July to September, and October to December, as will be seen on reference to Table I.

The relation between the shrimp-net and shank-net in catching power is shown in Table II. The results were obtained by averaging groups of hauls taken with the two kinds of net as far as possible on the same day and under similar conditions. The averages of the values thus obtained were then reduced to hourly catch, thus giving a fairly reliable picture of the relation between the nets in taking-power. The shank-net thus appears to be far superior to the shrimp-trawl in avoiding the capture of

## Showing Number of Hauls taken on Blackpool Closed Ground with Shrimp Trawl, Shank Net, and Fish Trawl during the years 1892 to 1906 inclusive.

| Net used | Shrimp Trawl | | | | Shank Net | | | | Fish Trawl | | | | Totals of all nets for the periods | | | | Yr'ly T'tls, all nets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year. | Jan. to Mar. | Apr. to June | July to Sept. | Oct. to Dec. | Jan. to Mar. | Apr. to June | July to Sept. | Oct. to Dec. | Jan. to Mar. | Apr. to June | July to Sept. | Oct. to Dec. | Jan. to Mar. | Apr. to June | July to Sept. | Oct. to Dec. | All periods. |
| 1892 | 0 | 2 | 4 | 2 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 6 | 15 |
| 1893 | 0 | 0 | 3 | 6 | 5 | 5 | 2 | 3 | 0 | 0 | 1 | 0 | 5 | 5 | 6 | 9 | 25 |
| 1894 | 3 | 3 | 2 | 2 | 5 | 4 | 6 | 1 | 0 | 0 | 11 | 0 | 8 | 7 | 19 | 3 | 37 |
| 1895 | 4 | 8 | 3 | 3 | 0 | 2 | 1 | 0 | 0 | 4 | 3 | 3 | 4 | 14 | 7 | 6 | 31 |
| 1896 | 1 | 1 | 0 | 0 | 4 | 2 | 4 | 6 | 1 | 1 | 4 | 2 | 6 | 4 | 8 | 8 | 26 |
| Quint. totals | 8 | 14 | 12 | 13 | 14 | 16 | 13 | 14 | 1 | 5 | 19 | 5 | 23 | 35 | 44 | 32 | 134 |
| 1897 | 1 | 1 | 0 | 3 | 6 | 4 | 2 | 6 | 0 | 0 | 5 | 3 | 7 | 5 | 7 | 12 | 31 |
| 1898 | 1 | 0 | 3 | 1 | 2 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 3 | 1 | 7 | 1 | 12 |
| 1899 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 4 | 0 | 5 |
| 1900 | 3 | 0 | 0 | 0 | 4 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 7 | 6 | 4 | 0 | 17 |
| 1901 | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 3 | 4 | 1 | 10 |
| Quint. totals | 7 | 4 | 7 | 5 | 12 | 10 | 10 | 6 | 0 | 2 | 9 | 3 | 19 | 16 | 26 | 14 | 75 |
| 1902 | 10 | 6 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 10 | 6 | 3 | 4 | 23 |
| 1903 | 5 | 2 | 2 | 1 | 18 | 8 | 2 | 2 | 0 | 0 | 2 | 2 | 15 | 10 | 5 | 7 | 37 |
| 1904 | 0 | 6 | 1 | 0 | 5 | 3 | 0 | 0 | 0 | 3 | 3 | 0 | 5 | 11 | 5 | 0 | 21 |
| 1905 | 2 | 2 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 2 | 8 | 3 | 5 | 7 | 11 | 6 | 29 |
| 1906 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 4 | 0 | 0 | 2 | 6 | 0 | 8 |
| Quint. totals | 17 | 13 | 9 | 7 | 18 | 14 | 3 | 4 | 0 | 9 | 18 | 6 | 35 | 36 | 30 | 17 | 118 |

TABLE II.

| Net used | Average number of Shrimps per hour | Average number of Undersized Fishes per hour | Average number of Young Fishes taken with each quart of Shrimps |
|---|---|---|---|
| Shrimp Trawl... | $5\frac{1}{8}$ Quarts | $6,175\frac{7}{8}$ | 1,155 |
| Shank Net ..... | $6\frac{6}{7}$ ,, | $1,642\frac{2}{3}$ | $239\frac{5}{9}$ |

young fish, and this with no loss or even a small gain in capture of shrimps. The shank-net hauls were made partly with the ordinary form, and partly with the patent Bar-net. Table III. shows the relation between the

TABLE III.

| Kind of net used | Average number of Undersized Fishes per hour | Average number of Shrimps per hour | Average number of Undersized Fishes taken with each quart of Shrimps |
|---|---|---|---|
| Ordinary Shank | 553 | 2·1 | 263·3 |
| Bar Shank ..... | 508·5 | 2·2 | 231 |

catching-powers of these two nets, the values being obtained in a similar way to those for shrimp-trawl and shank-net. It will be seen that the bar-net is slightly the superior both in avoidance of young fish and in capture of shrimps. Tables IV. and V. give the average catches per hour with one shank-net and one shrimp-trawl respectively, of plaice, dabs and shrimps on the Blackpool Closed Ground for the four seasons. The figures were

## Table IV.

### Showing Average Catch per hour of Shrimps and Undersized Fishes with Shank Net.

| Season | January to March | | | April to June | | | July to September | | | October to December | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Shrimps Pts. | Plaice No. | Dabs No. | Shrimps Pts. | Plaice No. | Dabs No. | Shrimps Pts. | Plaice No. | Dabs No. | Shrimps Pts. | Plaice No. | Dabs No. |
| 1892 | 0 | 0 | 0 | 3 | 112 | 78 | — | — | — | 22¼ | 956 | 2970 |
| 1893 | 15½ | 236 | 770 | 6¾ | 31 | 86 | ½ | 223 | 207 | 17¼ | 2293 | 864 |
| 1894 | 16¾ | 631 | 1227 | 2¾ | 80 | 155 | 5¼ | 96 | 119 | — | — | — |
| 1895 | — | — | — | 4¾ | 37 | 54 | 18 | 72 | 33 | — | — | — |
| 1896 | 14½ | 392 | 1625 | 1¼ | 71 | 23 | ½ | 114 | 449 | 11½ | 39 | 350 |
| Quint. totals. | 15¼ | 420 | 1207 | 3¼ | 66 | 79 | 6 | 151 | 202 | 17 | 1096 | 1395 |
| 1897 | 1¼ | 70 | 130 | 3¼ | 137 | 82 | 6 | 26 | 32 | 2 | 12 | 72 |
| 1898 | 12 | 51 | 752 | — | — | — | 4½ | 11 | 8 | — | — | — |
| 1899 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1900 | 7 | 9 | 1476 | 6 | 19 | 173 | ½ | 6 | 10 | — | — | — |
| 1901 | — | — | — | — | — | — | — | — | — | — | — | — |
| Quint. totals | 6¾ | 43 | 786 | 5 | 78 | 127 | 3⅝ | 14 | 17 | 2 | 12 | 72 |
| 1902 | — | — | — | — | — | — | — | — | — | — | — | — |
| 1903 | 10½ | 18 | 729 | 5 | 20 | 529 | 6½ | 3 | 33 | 21½ | 2 | 889 |
| 1904 | 8 | 4 | 3634 | 1 | 9 | 85 | — | — | — | — | — | — |
| 1905 | 1¼ | 64 | 707 | ⅔ | 70 | 32 | — | — | — | — | — | — |
| 1906 | — | — | — | — | — | — | — | — | — | — | — | — |
| Quint. totals | 6½ | 29 | 1890 | 2⅓ | 33 | 182 | 6½ | 3 | 33 | 21½ | 2 | 889 |

## Table V.

### Showing Average Catch per hour of Shrimps and Undersized Fishes with Shrimp Trawl.

| Season | January to March | | | April to June | | | July to September | | | October to December | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Shrimps Pts. | Plaice No | Dabs No. | Shrimps Pts. | Plaice No. | Dabs No. | Shrimps Pts. | Plaice No | Dabs No. | Shrimps Pts. | Plaice No. | Dabs No. |
| 1892 | — | — | — | 2 | 310 | 210 | 7½ | 490 | 126 | 11 | 1 | 241 |
| 1893 | — | — | — | — | — | — | 6 | 2916 | 3966 | 26 | 2182 | 786 |
| 1894 | 17½ | 3036 | 2864 | ¾ | 712 | 455 | — | — | — | 13½ | 617 | 1078 |
| 1895 | 6¼ | 751 | 2129 | ½ | 273 | 313 | ½ | 1106 | 254 | 12¼ | 2165 | 885 |
| 1896 | 36 | 2756 | 15200 | 5 | 543 | 121 | — | — | — | — | — | — |
| Quint. totals | 20 | 2183 | 6731 | 2 | 459 | 275 | 5 | 1504 | 1449 | 15¾ | 1241 | 747 |
| 1897 | 2½ | 326 | 4572 | 0 | 209 | 102 | — | — | — | 1¾ | 57 | 163 |
| 1898 | 0 | 606 | 399 | — | — | — | 15 | 389 | 1872 | 14 | 508 | 162 |
| 1899 | — | — | — | — | — | — | 1⅔ | 74 | 366 | — | — | — |
| 1900 | 16⅓ | 100 | 3509 | — | — | — | — | — | — | — | — | — |
| 1901 | 15 | 286 | 7399 | 1 | 214 | 517 | 0 | 135 | 340 | 1 | 130 | 1028 |
| Quint. totals | 8½ | 329 | 4722 | ½ | 212 | 309 | 5½ | 423 | 859 | 5½ | 232 | 451 |
| 1902 | 5¾ | 332 | 5305 | 2⅔ | 244 | 2159 | 3 | 99 | 1301 | 1⅓ | 174 | 186 |
| 1903 | 18 | 209 | 14121 | 2 | 34 | 745 | 6 | 42 | 929 | 32 | 20 | 1805 |
| 1904 | — | — | — | 9½ | 40 | 857 | 12 | 16 | 608 | — | — | — |
| 1905 | 6⅔ | 125 | 6152 | 0 | 59 | 391 | 4 | 74 | 499 | 6⅔ | 7 | 125 |
| 1906 | — | — | — | — | — | — | 0 | 196 | 2000 | — | — | — |
| Quint. totals | 10⅓ | 222 | 8526 | 3½ | 94 | 1038 | 5 | 85 | 1067 | 13⅓ | 67 | 705 |

obtained by averaging all the hauls taken in the season in question and reducing to average catch per hour. As the figures are too irregular for it to be possible to form any idea of variation directly from the tables, curves were drawn through points representing the values to be examined. Fig. 4 is a curve drawn through points corresponding to the average catch per hour with shank-net of dabs in the four seasons. To eliminate the small yearly difference in this variation, the whole period of fifteen years was considered. Fig. 3 is the curve of the same values for the shrimp-trawl. These show that the maximum catches of dabs are made in the winter, from November to February, and the minimum catches in the summer, from May to July. The very low position of the curves in June and July should not be taken as representing the actual values, but as indicating the probability that if an average were obtainable for the catches taken at this time, it would be lower than the averages for catches either before or after it. Figs. 1 and 2 are the curves for yearly variation in number of plaice caught per hour on the ground with shrimp-trawl and shank-net respectively, each curve representing the same season throughout the fifteen years considered. The curves have not been drawn through the points representing the actual values, but have been smoothed in the same way as were the monthly averages for the Mersey Banks (see page 87), so that irregular variations are disregarded and the general tendency of the figures shown. Both sets of curves show a marked decrease in the number of plaice taken per hour on the Closed Ground since 1892. This decrease is least visible in the curve for April to June. Other curves have been drawn, but are not included, as they show little sign of any regular variation. Thus, the curves for hourly catch of shrimps are so irregular that no deductions could

possibly be drawn. The curves of yearly variation in hourly catch of dabs show that the fluctuations in numbers caught are mainly confined to the winter seasons, October to March, being then about four times as great as in the summer.

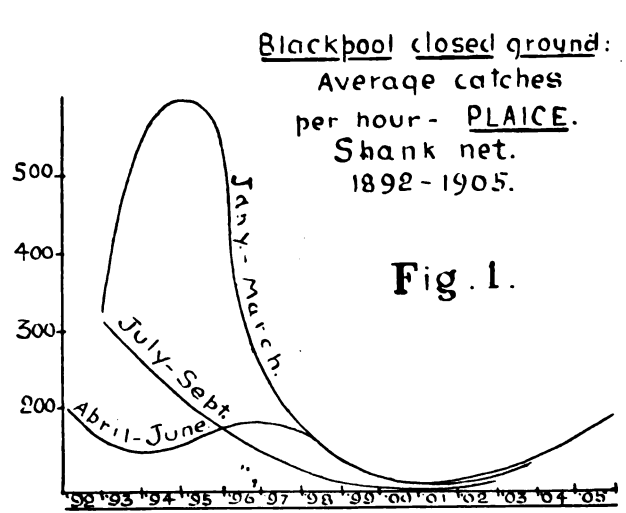


Fig. 1.

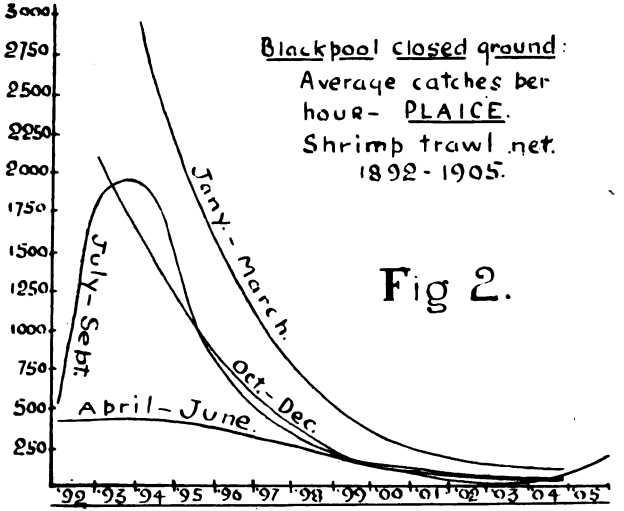


Fig 2.

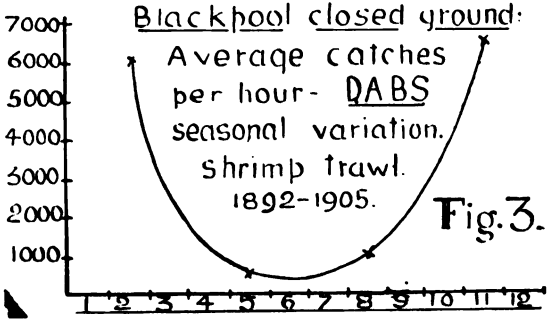


Fig.3.

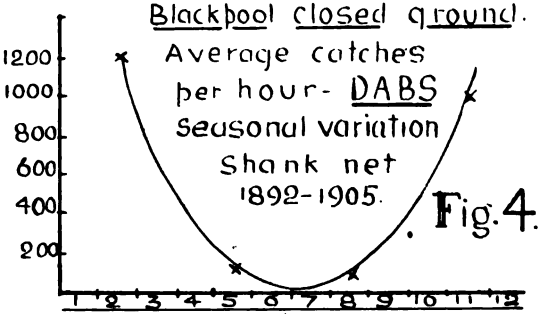


Fig.4.

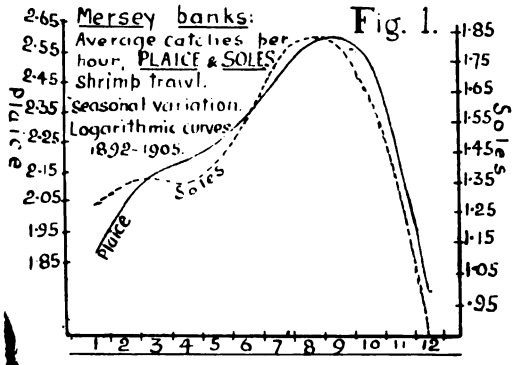


Fig. 1.

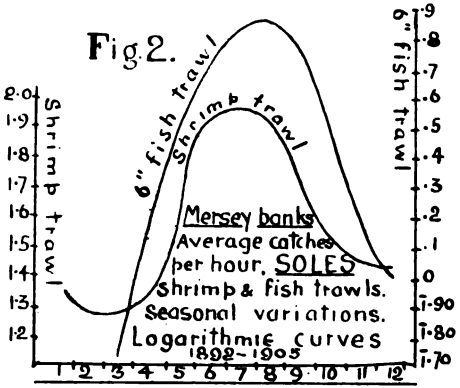


Fig. 2.

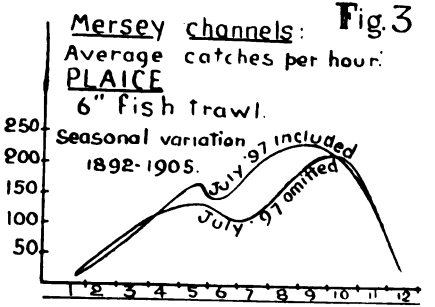


Fig. 3

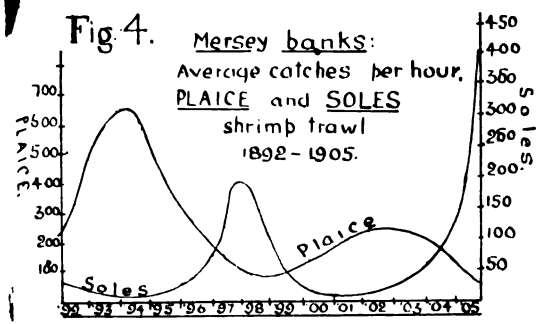


Fig. 4.

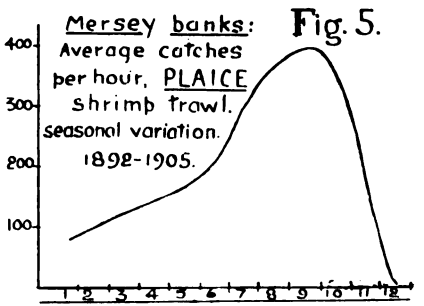


Fig. 5.

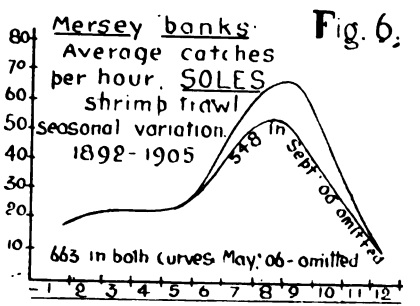


Fig. 6.

PLATE V.

# AN EXAMINATION OF THE EXPERIMENTAL HAULS MADE IN THE MERSEY ESTUARY DURING THE PERIOD 1892 TO 1906 INCLUSIVE.

(Plate V.)

By H. J. Buchanan Wollaston.

The present paper deals with the records of the experimental hauls made on the Mersey Banks and in the adjoining Channels, by the L. and W.S.F. steamer "John Fell," and the New Brighton police cutter. The material consists of several hundred sheets, dealing with nearly 800 hauls—there being 260 hauls made with shrimp-trawl nets, 70 with fish-trawls of various forms, and 13 with shank-nets, all on the banks; also 281 with fish-trawls, 163 with shrimp-trawls, and 3 with shank-nets, all taken in the channels between the banks. It was evident on examination of the records that the number of hauls made with fish-trawls on the banks, and with shank-nets both on the banks and in the channels were quite insufficient to afford reliable conclusions. The shrimp-trawl-net hauls, both in the channels and on the banks, and the six inch fish-trawl-net hauls in the channels, are, however, sufficiently numerous to warrant statistical treatment, and the results have some interest, especially with regard to the variations from month to month in the numbers of plaice and soles on the banks. The method adopted was as follows: Every haul was separately reduced to an hourly catch, that is, to take a simple case, if the haul was of two hours' duration the result was divided by 2. From all the hauls in each month so reduced, an average haul was calculated, giving the numbers of plaice and soles caught per hour's fishing. The observations were, however, made rather irregularly, and so in order to get a more reliable average catch per hour for each month, the whole period of fifteen years

(1892-1906) was considered, that is, for instance, all the average hourly hauls for January were added together, and a new average, giving the number of fish caught per hour's fishing for the month of January (1892-1906), was thus obtained. Similarly, to find the yearly variation, which was only possible in the case of the summer months, owing to lack of data for the winter, an average hourly catch for the six-monthly period, May to October, was obtained in each year, and the variation of this average from year to year was studied. Curves were drawn through points corresponding to these averages, and since it was found that these points were too irregularly distributed to give reliable results, they were modified in the following manner:—The values representing the average catches were arranged in chronological order, and the first and last were taken as correct. For each of the other monthly averages a new value was substituted, obtained as follows:—The average catches for the month in question and that immediately preceding and succeeding it were added together and the sum divided by three. This is the well-known statistical device of "taking three-monthly averages monthly." In some cases the figures thus obtained had to be again treated in the same way before it was found possible to draw a really smooth curve through the points, showing distinct maxima and minima. The following figures, those for average catches of plaice with the shrimp-trawl net, will serve to show the method.

| | Original Figures. | | First Smoothing. |
|---|---|---|---|
| Jan. ..... | 72 ... | (taken as correct) ... | 72 |
| Feb. ..... | 93 ... | $\frac{72 + 93 + 182}{3}$ = | 116 |
| Mar. ..... | 182 ... | $\frac{93 + 182 + 94}{3}$ = | 123 |
| April ..... | 94 ... | $\frac{182 + 94 + 155}{3}$ = | 144 |
| May ..... | 155 ... | ... ... ... | &c. |
| &c. | | | |

This method may appear somewhat artificial, but is not so in reality to any great extent, as it merely means that the values of the numbers for the months immediately before and after each given month are allowed an influence in determining the new values for that month.

Now if we proceed to construct curves showing the variation in the average hourly catches of plaice and soles made per month on the banks, we notice a distinct similarity in the shapes of these curves, i.e., where there is an increase in the number of plaice, there is also an increase in the number of soles, and vice versâ. We do not, however, know whether the rate of increase is the same in the two cases, that is, for instance, whether a 10 per cent. increase in plaice would correspond with a 10 per cent. increase in soles. Now, in order to find whether this rate of increase is the same or different, we may take, instead of the actual numbers of plaice and soles caught, the logarithms of those numbers, and the curves constructed from the latter values show the relation between the rates of increase and decrease, that is to say, if the two curves have the same shape and height the rate of increase is the same in the two cases. This has been done (figs. 1, 2) for the monthly variation of plaice and soles on the Mersey banks, and also for the monthly variation of average hourly catch of soles with shrimp-trawl and six inch mesh fish-trawl.

We are now in a position to attempt to draw conclusions from the results obtained by the above methods. The data are not sufficient to warrant any conclusion regarding yearly variation except in the case of numbers of plaice and soles caught by the shrimp-trawl net on the banks in the summer months. The curves plotted from these values seem to indicate a complementary relation-

ship, plaice increasing as soles decrease, and vice versâ (see fig. 4).

In the monthly variation there is, on the other hand, direct correspondence between the hourly catches of plaice and soles on the banks with the shrimp-trawl (see figs. 5, 6), plaice increasing as soles increase, and at approximately the same rate (see fig. 1), though the period of greatest abundance is slightly earlier in the case of soles than in that of plaice, the maximum for soles being in August, while that for plaice is in September. Regarding plaice taken in the channels no very reliable conclusion can be drawn, the data being too scanty, but the greatest catches seem to have been made at the same time as on the banks (see fig. 3). In the case of soles taken in the channels, the curves of average catches with shrimp-trawl, and six inch fish-trawl show distinct relation to each other, both as to the position of the maximum catches and in rate of increase (see fig. 2), that is to say, if large soles increase, small soles increase in approximately the same proportion. The maximum is somewhat earlier for soles in the channels than on the banks.

In dealing in the future with separate yearly returns, the curves given here for monthly variation might be regarded as the standard forms, and the curve of monthly variation for any single year, if it differs widely from these standards, might be looked upon as rather exceptional. Of course these curves may differ considerably in different localities.

The tables of monthly averages, and the curves of monthly and yearly variation mentioned above are appended:—

## Average Catch per Hour of Plaice and Soles on the Mersey Banks with Shrimp-Trawl.

| | January | February | March | April | May | June | July | August | September | October | November | December | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1892 | ..... | ..... | ..... | ..... | ..... | ..... | 90 | 153 | ..... | 537 | 86 | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | 44 | 21 | ..... | 3 | 0 | ..... | Soles |
| 1893 | 45 | 129 | ..... | ..... | 115 | 494 | ..... | 707 | 2405 | 373 | 195 | 81 | Plaice |
| | 0 | 5 | ..... | ..... | 2 | 12 | ..... | 34 | 31 | 3 | 1 | 0 | Soles |
| 1894 | 217 | 134 | 295 | 178 | 661 | 402 | 170 | 556 | 571 | 225 | ..... | ..... | Plaice |
| | 7 | 5 | 60 | 15 | 31 | 38 | 20 | 16 | 10 | 8 | ..... | ..... | Soles |
| 1895 | 6 | ..... | 25 | 57 | 55 | 59 | 586 | 456 | 2315 | 813 | 189 | 62 | Plaice |
| | 0 | ..... | 0 | 1 | 18 | 6 | 24 | 29 | 5 | 0 | 0 | 0 | Soles |
| 1896 | ..... | ..... | 594 | 279 | 317 | 568 | 914 | 206 | ..... | 120 | ..... | ..... | Plaice |
| | ..... | ..... | 4 | 0 | 3 | 10 | 23 | 1 | ..... | 42 | ..... | ..... | Soles |
| 1897 | ..... | 94 | ..... | 102 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | 34 | ..... | 6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1898 | ..... | ..... | ..... | ..... | ..... | ..... | 111 | 130 | 92 | 85 | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | 190 | 339 | 119 | 155 | ..... | ..... | Soles |
| 1899 | ..... | ..... | ..... | ..... | ..... | 40 | 30 | 167 | 95 | 10 | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | 22 | 43 | 127 | 105 | 38 | ..... | ..... | Soles |
| 1900 | ..... | ..... | ..... | 9 | ..... | 51 | 35 | 133 | 72 | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | 20 | ..... | 46 | 13 | 50 | 4 | ..... | ..... | ..... | Soles |
| 1901 | ..... | ..... | 8 | 1 | 1 | 100 | 45 | 661 | 388 | 423 | 80 | 1 | Plaice |
| | ..... | ..... | 8 | 3 | 23 | 26 | 23 | 63 | 12 | 2 | 1 | 0 | Soles |
| 1902 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1903 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1904 | ..... | ..... | ..... | ..... | 18 | ..... | ..... | ..... | 459 | ..... | 4 | 44 | Plaice |
| | ..... | ..... | ..... | ..... | 7 | ..... | ..... | ..... | ..... | ..... | 22 | 0 | Soles |
| 1905 | 2807 | 20 | 7 | 28 | 21 | 116 | 58 | 78 | 122 | 24 | 40 | 34 | Plaice |
| | 0 | 3 | 0 | 7 | 38 | 5 | 170 | 20 | 3 | 168 | 25 | 9 | Soles |
| 1906 | 21 | 88 | 163 | 103 | 53 | 55 | ..... | ..... | 22 | ..... | ..... | 5 | Plaice |
| | 85 | 45 | 115 | 111 | 663 | 37 | ..... | ..... | 548 | ..... | ..... | 35 | Soles |

## Average Catch per Hour of Plaice and Soles in the Mersey Channels with Shrimp-Trawl.

| | January | February | March | April | May | June | July | August | September | October | November | December | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1892 | ..... | ..... | ..... | 95 | 13 | ..... | ..... | 301 | ..... | 881 | 383 | 107 | Plaice |
| | ..... | ..... | ..... | 4 | 10 | ..... | ..... | 35 | ..... | 1 | 1 | 0 | Soles |
| 1893 | ..... | 115 | 147 | 201 | 248 | 288 | ..... | 46 | 594 | 263 | 304 | 440 | Plaice |
| | ..... | 2 | 6 | 5 | 10 | 5 | ..... | 14 | 27 | 4 | 0 | 0 | Soles |
| 1894 | 420 | 296 | ..... | ..... | 246 | 433 | 315 | 122 | ..... | ..... | ..... | 201 | Plaice |
| | 0 | 7 | ..... | ..... | 19 | 31 | 47 | 6 | ..... | ..... | ..... | 0 | Soles |
| 1895 | ..... | ..... | 20 | 31 | 46 | 337 | ..... | ..... | 166 | 35 | 822 | ..... | Plaice |
| | ..... | ..... | 0 | 0 | 6 | 44 | ..... | ..... | 11 | 0 | 0 | ..... | Soles |
| 1896 | 1197 | 365 | ..... | 979 | ..... | ..... | ..... | ..... | 120 | ..... | ..... | ..... | Plaice |
| | 0 | 0 | ..... | 13 | ..... | ..... | ..... | ..... | 57 | ..... | ..... | ..... | Soles |
| 1897 | 129 | 126 | ..... | ..... | ..... | ..... | ..... | 1278 | 343 | 111 | ..... | ..... | Plaice |
| | 34 | 116 | ..... | ..... | ..... | ..... | ..... | 197 | 31 | 48 | ..... | ..... | Soles |
| 1898 | 1652 | ..... | ..... | ..... | ..... | ..... | 632 | 49 | 164 | 810 | 75 | ..... | Plaice |
| | 90 | ..... | ..... | ..... | ..... | ..... | 275 | 125 | 133 | 148 | 190 | ..... | Soles |
| 1899 | ..... | ..... | ..... | ..... | ..... | 37 | ..... | 11 | 73 | 51 | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | 89 | ..... | 4 | 31 | 24 | ..... | ..... | Soles |
| 1900 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1901 | ..... | 6 | 23 | ..... | 1 | 63 | ..... | ..... | ..... | ..... | 110 | ..... | Plaice |
| | ..... | 0 | 6 | ..... | 11 | 5 | ..... | ..... | ..... | ..... | 0 | ..... | Soles |
| 1902 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1903 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1904 | ..... | ..... | ..... | ..... | 17 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Plaice |
| | ..... | ..... | ..... | ..... | 150 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Soles |
| 1905 | 39 | ..... | 50 | 277 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | Plaice |
| | 2 | ..... | 37 | 1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 112 | Soles |
| 1906 | ..... | 23 | ..... | ..... | 58 | 6 | ..... | ..... | ..... | 256 | 599 | ..... | Plaice |
| | ..... | 71 | ..... | ..... | 119 | 41 | ..... | ..... | ..... | 3 | 3 | ..... | Soles |

AVERAGE CATCH PER HOUR OF PLAICE AND SOLES IN THE MERSEY CHANNEL WITH 6IN. FISH TRAWL.

| | January | February | March | April | May | June | July | August | September | October | November | December | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 892 | | | | | 8 | 35 | 198 | 33 | 83 | | | | Plaice |
| | | | | | 0 | 2 | 1 | 1 | 2 | | | | Soles |
| 893 | | 30 | 13 | | | | 150 | 463 | 73 | 161 | | 5 | Plaice |
| | | 0 | 0 | | | | 2 | 0 | 2 | 2 | | 4 | Soles |
| 894 | | | | | | | | | 1027 | | | | Plaice |
| | | | | | | | | | 0 | | | | Soles |
| 895 | | | | | | | | | 322 | 612 | | | Plaice |
| | | | | | | | | | 0 | 0 | | | Soles |
| 896 | | | | | | | 34 | | | 967 | | | Plaice |
| | | | | | | | 2 | | | 0 | | | Soles |
| 897 | | | | | | | 3211 | | | | | | Plaice |
| | | | | | | | 0 | | | | | | Soles |
| 898 | | | | | | | | | | | | | Plaice |
| | | | | | | | | | | | | | Soles |
| 899 | | | | | | 29 | | | | | | | Plaice |
| | | | | | | 3 | | | | | | | Soles |
| 900 | | | | | | | | | | | | | Plaice |
| | | | | | | | | | | | | | Soles |
| 901 | | | | | | | 1 : 7 | | | | 32 : 283 | | Plaice |
| | | | | | | | 8 : 11 | | | | 5 : 0 | | Soles |
| 902 | | 22 | | | 639 | | 50½ | 437 | | | | | Plaice |
| | | 0 | | | 0 | | 7 | 5 | | | | | Soles |
| 903 | | | | 294 | | 131 : 30 | 41 | 143 : 165 | | | | 7 | Plaice |
| | | | | 0 | | 13 : 9 | 8 | 4 : 9 | | | | 0 | Soles |
| 904 | | 2 | 26 | | | | 54 : 26 | 6 | 42 : 0 | 55 | | | Plaice |
| | | 0 | 0 | | | | 16 : 3 | 44 | 9 : 13 | 7 | | | Soles |
| 905 | | | 100 | 2 | 48 | 11 | 29 | | | 566 : 298 | 66 : 39 | | Plaice |
| | | | 0 | 1 | 5 | 10 | 23 | | | 1 : 0 | 0 : 0 | | Soles |
| 906 | 0 | | | | | 30 | 10 | 10 | 22 : 74 | 80 : 182 | | | Plaice |
| | 0 | | | | | 0 | 16 | 4 | 5 : 3 | 0 : 1 | | | Soles |

NOTE.—Where there are two numbers in one line in any square the second is the average of hauls made with a fish-trawl having pockets and tails of 6in. mesh, the other that for the ordinary 6in. mesh trawl.

# AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.

By W. A. Herdman, F.R.S., and Andrew Scott, A.L.S.

## INTRODUCTORY.

The objects of this detailed investigation into the Plankton of a limited marine area are twofold:—

(1) To study the distribution of the Plankton as a whole and of its various constituents during the year, and

(2) To attempt to arrive at some estimate of the representative value of such samples as are collected in our plankton nets.

Of the fundamental importance of plankton work in regard to fishery questions of a wide nature there can be no doubt, and of the absolute necessity of the determination of the value of samples and of arriving at some estimation of their representative nature there can be still less difference of opinion.

In former reports* we have shown that our results around the Isle of Man and in other parts of the Irish Sea show great diversity in the plankton, both quantitatively and qualitatively when considered according to locality or according to date but in all these former reports we have felt that fuller information might enable us to reduce the apparent chaos to order, and might reveal some method or definite sequence in a distribution which seemed indefinite or irregular. Consequently we have endeavoured during the last year to make our observations as frequent, full

* Twentieth Annual Report of the Liverpool Marine Biology Committee, Dec., 1906; Presidential Address to the Linnean Society of London, May, 1907; and Twenty-first Annual Report of the L.M.B.C., Dec., 1907.

and detailed as possible, and the result is that we have now at our disposal a much larger number of samples than has ever been collected before in such a limited period from the Irish Sea—possibly a greater number of samples than has been obtained in one year from any other part of the British coasts. The total number is 885 obtained from our northern portion of the Irish Sea bounded by lines drawn between Holyhead, Liverpool, Barrow and Port Erin, in the year 1907; and of these the majority, 650, are from a very limited area in the immediate neighbourhood of Port Erin.

At the South end of the Isle of Man, where these gatherings were taken, there are very important fishing grounds which are frequented by trawlers from Lancashire and from Ireland, as well as by the Manx fishermen. This, as well as the circumstance that we have there, within a few miles, a sheltered sandy bay, an exposed rocky coast, a narrow strait and an area of open sea with depths reaching to 70-80 fathoms, has led us to consider Port Erin a very suitable locality for a more exhaustive or intensive study of the Marine Plankton than has yet been attempted on our coast.

## Previous Local Work.

The Liverpool Marine Biology Committee started a scheme for taking weekly plankton gatherings in this district of the Irish Sea as long ago as 1888, and although as the result of weather, changes in the staff and other varying conditions, many gaps have been left from time to time in the series, that aim has been constantly before us, and the practice has been kept up intermittently. A good deal of material was collected from the neighbourhood of Puffin Island, and from Port Erin in these early years, and was examined and reported upon by the late

Mr. Isaac C. Thompson. In 1897 a more definite scheme was organised for the collection of plankton weekly from six different localities off the coasts of Lancashire, Cheshire and the Isle of Man; and the material so gathered was examined, and reported upon, as part of the Sea Fisheries work of the district. The Annual Reports of the Liverpool Marine Biology Committee and the Lancashire Sea Fisheries Laboratory Reports contain, from time to time, articles on the plankton of the Irish Sea or scattered notices of occurrences. Thus Mr. E. T. Browne, working at Port Erin from April to June, 1893, noted that *Ceratium tripos*, *C. fusus* and *Peridinium divergens* were nearly always present in his gatherings; that there was "a great decrease of Copepoda when the sea is full of Diatoms"; and that Oikopleura is abundant with ova at the end of April, and that the young individuals are found at the end of May. Mr. H. C. Chadwick, in 1894, recorded the abundance of larval and post-larval worms in May, in an article on "Plankton Observations," in the Report for 1897 (p. 17). He noted a great abundance of Diatoms in spring, an increase of pelagic Coelenterata and Copepoda in early summer, the appearance of fish-eggs and embryos and larval fish at Easter, a great increase in Medusae and Ctenophora in later summer, and the abundance of Dinoflagellates in late summer and autumn.

A summary account of the Port Erin plankton throughout the year was given in 1899 (13th Report, p. 29), and in this the maximum of Diatoms at the end of March is noted. also a maximum of larval forms in the last weeks in June, of Medusae in July, and of Zoeas and other Decapod larvae towards the end of August. Oikopleura attained its maximum that year at the end of September. The presence of the three species of

Ceratium—*C. tripos*, *C. fusus* and *C. furca*—throughout the year is also noted.

In the Sea Fisheries Laboratory Report for 1892 the great profusion of Diatoms in the spring, and their replacement later on by Copepoda, was drawn attention to. In the Reports for 1904, 1905 and 1906 there were special articles on the Plankton of the Irish Sea, in which the spring maximum of the Diatoms and other features of the distribution throughout the year were noted. In the 1905 Report, 365 gatherings had been examined, and in the following year (1906) 400 gatherings. These numbers, the largest up to that date, have, however, been more than doubled on the present occasion (1907).

In these previous accounts we have used the terms "numerous," "abundant," &c., or the symbols "r" (rare), "c" (common), "fr" (frequent), &c., as is usually done by other investigating authorities; but this year we have adopted the plan of counting the organisms in a number of samples from each gathering, and of estimating from these the approximate total numbers of each kind of organism present. The exact method employed has been as follows:—

### Method of Estimation.

After carefully removing pieces of sea-weed and other foreign matters, the sample is thoroughly shaken up and then allowed to stand and settle for a week. In the case of a very small catch, the sample is first transferred to a narrow tube. After standing for a week, a mark is made on the bottle, indicating the exact height occupied by the organisms. The whole sample is then washed through a silk sieve of 36 meshes to the inch, into one of 200 meshes to the inch. By this process the Diatoms, Dinoflagellates and allied minuter organisms, along with the Copepod Nauplii and young Copepoda, are

separated from the larger organisms such as Sagitta, larval Decapods, and adult Copepoda, except perhaps Oithona. The two portions thus obtained are carefully transferred to graduated tubes, so that they can be each made up to a known bulk with fresh water. The larger organisms are examined first. If the bulk of the catch which is left on the coarse silk sieve is not large, then a direct enumeration of the organisms can be made at once by turning the contents of the tube on to a glass plate with a dark background and examining the animals in a good light with a strong hand magnifying glass, or low power of the microscope if necessary. The various species are recorded as the sample is gone over, and the totals are added up at the end of the examination. If the sample to be examined, however, be too large for a direct and complete enumeration, then it is first gone over carefully and the rarer or larger organisms are counted and removed. The remainder are then returned to the graduated tube and are diluted with water to a workable extent. The tube is then thoroughly shaken up so that a complete mixture or dissemination of the organisms through the fluid is effected. A graduated dipping tube about $\frac{3}{16}$ of an inch bore, without any contraction at the end and capable of taking up $\frac{1}{5}$ of a cubic centimetre, is quickly inserted into the mixture, $\frac{1}{5}$ c.c. is taken up and is put on a glass slide. In this way at least five similar samples are withdrawn, care being taken to shake up the mixture afresh previous to every fresh dip. The samples thus obtained are then worked over under the microscope and all the species are identified and enumerated. The average of these countings is taken, and this is multiplied by the factor representing the amount of dilution—thus, if the sample is made up to 10 cubic centimetres, then the factor will be 50. The same method is employed in estimating the Diatoms and

other allied organisms, but in the case of these minuter forms several dilutions may be required before all the species can be estimated. The scarce forms are taken first, and after one or two further dilutions the numbers of the more abundant species are arrived at. In dealing with samples containing Rhizosolenia it was found necessary to dilute the collection to 5,000 cubic centimetres before the numbers in $\frac{1}{5}$ c.c. could be counted. The examination of the Diatoms, &c., is carried out, under the microscope, with either a $\frac{2}{3}$ inch English objective or a No. 3 Leitz objective (higher powers being used when necessary for the critical examination of any species), the $\frac{1}{5}$ c.c. sample being passed very slowly backwards and forwards across the stage. In front of the worker there is a tray containing a number of empty glasses with names corresponding to the species that are usually found. A vessel containing small shot is placed close to the hand, and as the sample is passed under the objective of the microscope, each organism seen is recorded by placing one of the shot into the corresponding glass. When the examination is completed the shot in each glass is counted and the estimation made. This entire operation is repeated with at least five distinct dips from each gathering. This method of estimation was tested both against several dilutions of the one mixture, and also against actual countings of the organisms present, and the variation in all cases was found to be of practically no account. The bottle which originally contained the sample, and which was marked to show the height occupied by the organisms, is now placed under a graduated burette filled with water. The stopcock is opened and the water allowed to run into the bottle up to the mark exactly. The loss from the burette is read off and this represents the volume of the catch in cubic centimetres.

## DISCUSSION OF THE OBSERVATIONS.

The majority of the hauls discussed below were taken from the S.Y. "Ladybird" during the two critical periods of the year, spring (April) and late summer (August and September), when certain constituents in the plankton attain their maxima of development: while the other observations were taken throughout the year from smaller boats in the inshore waters of Port Erin Bay.

During the spring, a month (March 28th to April 27th) was devoted to this work from the "Ladybird," and in the 23 working days during that period we took in all 276 samples, an average of 12 per day.

In the summer and autumn (August 9th to September 20th) the "Ladybird" was again engaged on this work, and during this period 300 gatherings were taken in the 30 working days, an average of 10 per day. On one expedition (September 20th) 36 gatherings were taken in an afternoon, in a small area of only about two miles extent, as follows:—

LOCALITY A:—6 miles out, W.N.W. of Bradda, over 30 fms.

1. Hensen and Nansen nets let down to 30 fms. and hauled up 10 fms. (30-20).
2. ,, ,, ,, 20 fms. ,, ,, 10 fms. (20-10).
3. ,, ,, ,, 10 fms. ,, ,, 10 fms. (10-0).
4. ,, ,, ,, 30 fms. ,, ,, open to surface (30-0)

Weighted open net (A) and two surface nets (A1 and A2) along with shear net (Sh. 1) at 15-20 fms.

Weighted open net (B) and two surface nets (B1 and B2) along with shear net (Sh. 2) at 7-8 fms.

(These each ½-hour hauls; the one set taken immediately after the other).

Mill water bottle at 20 fms., strained at the time.
,, ,, 20 fms., strained on shore.

LOCALITY B:—8 miles out W.N.W. of Bradda, over 30 fms.

1. Hensen and Nansen nets let down to 30 fms. and hauled up 10 fms. (30-20).
2. ,, ,, ,, 20 fms. ,, ,, 10 fms. (20-10).
3. ,, ,, ,, 10 fms. ,, ,, 10 fms. (10-0).
4. Nansen (alone) ,, ,, 30 fms. ,, ,, to surface (30-0).

Weighted open net (C) and 2 surface nets (C1 and C2) along with shear net (B1) at 7-8 fms.

Weighted open net (D) and 2 surface nets (D1 and D2) along with shear net (B2) at 15-20 fms.

(These each ½-hour hauls; the one set taken immediately after the other).

Mill water bottle at 20 fms., at 10 fms., and at 5 fms.

The fixed stations at which observations were generally made are shown in the adjoining plan (fig. 1), where I and II indicate off-shore stations, respectively five and ten miles from land; and III, IV and V show the along-shore stations, one to the north towards Niarbyl, one to the south near the Calf Island, and one in the "southern sea" off Spanish Head—all, except II, in water of much the same depth, about 20 fathoms. The region covered measures about ten miles from east to west (out to sea) and rather less from north to south (along the coast), but the area investigated was really very much less, being confined to the above-mentioned stations from which plankton samples were taken and the in-shore waters of the Bay.

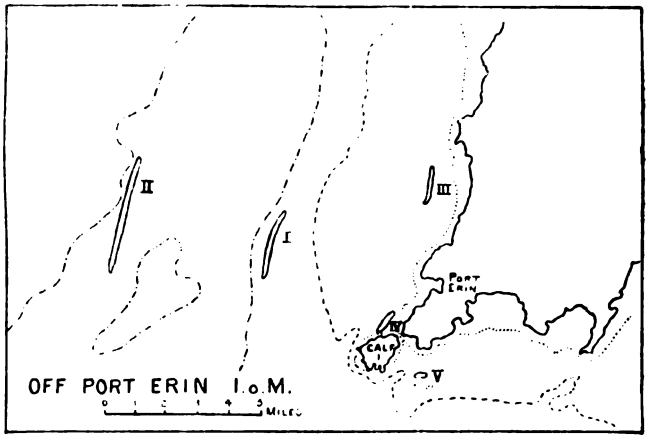


FIG. 1.—Plankton Stations off Port Erin.

The usual practice, in our work on the yacht, was this:—At each station, after taking the bearings, depth, &c., we first lowered two vertical nets, the Petersen-Hensen and the Nansen, to a depth of 20 fathoms, pulled them up slowly through 10 fathoms, and then closed them by "messengers" run down the line. This gave us

samples, taken vertically with these two very different nets, of the organisms present in the water between 10 and 20 fathoms. After that three ordinary horizontal open tow-nets exactly alike in all respects (size, shape, mesh, age) were put over—one (A) with a weight attached was allowed to sink to a depth of about 10 fathoms, from which it gradually rose as the ship went slowly ahead: while the other two (B and C), unweighted, remained continuously at or just under the surface and worked side by side like a pair of sharks or porpoises swimming in our wake. These two last nets ought, if there is any uniformity whatever in the plankton even in the most limited areas, to give similar results, and of course they did so in many cases. The purpose in taking the two similar surface nettings side by side was to show this, and also to test the reliability of the sample: for it was usually considered a more valid sample when these two nets agreed in their evidence. Where, under the circumstances stated above, the gatherings differed notably, there must have been some accident in the working of the nets or some irregularity in the distribution of the plankton, such as, no doubt, will sometimes be encountered when traversing the edge of a swarm of gregarious organisms; and it is important to get some evidence as to how frequently such accidents or irregularities may be met with. For example, on April 2nd, at along-shore Station III, the two surface-nets used together gave 17 c.c. and 42·5 c.c. of material respectively; on April 9th, at Station I, 2·5 and 8 c.c. respectively: and on April 24th, at Station II, they gave 7 c.c. and 15 c.c. respectively. On many occasions, of course, they were very similar, and on some almost identical in their catch (see examples given below). Each of these horizontal nets was hauled for 15 minutes.

The net A (which may be called the weight-net) is of use as having traversed a wider range, 0 to 10 fathoms, so as to sample all the water above the zone traversed by the vertical nets, and it frequently, and in fact usually, obtained a larger gathering and showed a greater variety of organisms than either the deeper, closing (vertical) or the open surface nets.

On some occasions, at the "along-shore" stations (e.g., 2 miles off Bradda Head) hauls were taken with a new "shear-net" made on the principle of the Heligoland "Scherbrutnetz" (*Conseil International—Rapports et Procès-verb.*, vol. ii, p. 62, 1904). This was used as a mid-water net—being lowered to a depth of 5 to 10 fathoms, where, through the action of the shearing plate, placed like a vertical otter-board, it remained even when the ship went ahead at a moderate speed, and so formed a most efficient instrument of capture in waters where the ordinary net cannot be towed. The mouth measured nine feet in circumference, the net was over ten feet in length, and being formed of rather coarse mesh caught quantities of the larger organisms of the plankton such as Sagitta, Medusae, Ctenophora, Zoëas, the larger Copepoda and some young fishes.

The variation in the bulk of the catch on different days with the same net, used so far as was possible under the same conditions, was very remarkable. The accompanying diagram shows graphically the range in quantity of the total catches with each kind of net during April, 1907. The Nansen net catches ranged in quantity from 0·5 c.c. to 164 c.c., the Petersen-Hensen from 0·5 c.c. to 64·5 cc., the weighted open tow-net from 5·5 c.c. to 41 c.c., the surface open tow-nets from 1 c.c. to 42·5 c.c., and the shear net from 11 cc. to 78·5 c.c. The black columns in the diagram (fig. 2) are drawn to scale.

and so give a true representation of the proportional bulk of the largest and smallest catches with each net.

We have considered it unnecessary to print in this first report the details of the nearly nine hundred tabular forms containing the results of the hauls, but we shall give various lists extracted from these tables, and curves derived from the lists, and we shall also reproduce a certain

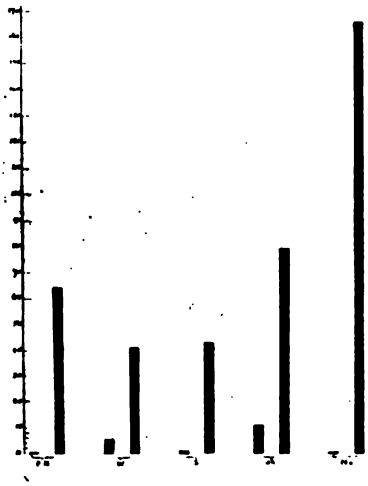

FIG. 2.—Showing by proportional columns the range in quantity taken by the various Plankton nets in April, 1907.

number of the sheets of records as samples of different nets, dates and localities. The complete series of sheets are deposited in the Zoological Department of the University of Liverpool and will be available for consultation there, and may possibly, if it be found desirable, be printed in a future report along with the results of a further year's work.

## Total Plankton throughout the Year.

We give now, as the first summary statement from our Forms, and in further illustration of the great quantitative range shown by the gatherings taken on different days, the following record of the "total plankton," reduced to the average* per haul for each individual day:

| Date. | Average per Haul. | Date. | Average per Haul. |
|---|---|---|---|
| Jan. 8 | 1·2 c.c. | April 25 | 10 c.c. |
| ,, 18 | 1 ,, | ,, 26 | 9 ,, |
| Feb. 5 | 1·2 ,, | ,, 27 | 10 ,, |
| ,, 22 | 2 ,, | May 8 | 11 ,, |
| ,, 26 | 0·5 ,, | ,, 18 | 5 ,, |
| Mar. 14 | 1·5 ,, | ,, 24 | 6 ,, |
| ,, 26 | 6 ,, | June 11 | 20 ,, |
| ,, 27 | 14·5 ,, | ,, 15 | 13·5 ,, |
| ,, 29 | 9 ,, | ,, 27 | 15 ,, |
| April 1 | 17 ,, | July 5 | 4 ,, |
| ,, 2 | 31 ,, | ,, 12 | 3·5 ,, |
| ,, 3 | 42·5 ,, | ,, 17 | 4·5 ,, |
| ,, 4 | 31 ,, | ,, 31 | 11 ,, |
| ,, 5 | 30 ,, | Aug. 9 | 14·5 ,, |
| ,, 6 | 34 ,, | ,, 10 | 25 ,, |
| ,, 8 | 23·5 ,, | ,, 12 | 12·5 ,, |
| ,, 9 | 15 ,, | ,, 13 | 4 ,, |
| ,, 10 | 17 ,, | ,, 14 | 18 ,, |
| ,, 11 | 21 ,, | ,, 15 | 18·5 ,, |
| ,, 13 | 25 ,, | ,, 16 | 12 ,, |
| ,, 15 | 13 ,, | ,, 17 | 13 ,, |
| ,, 16 | 11 ,, | ,, 19 | 12 ,, |
| ,, 17 | 51 ,, | ,, 20 | 12 ,, |
| ,, 18 | 14 ,, | ,, 21 | 4·5 ,, |
| ,, 19 | 17 ,, | ,, 22 | 6 ,, |
| ,, 22 | 13 ,, | ,, 23 | 3 ,, |
| ,, 23 | 22 ,, | ,, 24 | 18 ,, |
| ,, 24 | 16 ,, | ,, 26 | 5 ,, |

* We desire to point out that as the nets used were not all comparable, the vertical nets catching as a rule less and the shear net more than the open horizontal tow-nets, no conclusions are based solely on the details of this record. Moreover, during the greater part of the year, only open horizontal nets were used, while in spring and autumn, while the yacht was at work, the vertical nets and the shear net were used in addition. But as the number of observations is large, and the non-comparable nets more or less neutralise one another, the average per haul is probably a fair representation of the plankton caught. The averages may be lowered unduly by the vertical nets on some days, or raised too much by the shear net on others, but must be substantially correct for the weeks and months, and so the list serves to show the range in variation and the seasonal change—and that is all we use it for.

| Date. | Average per Haul. | Date. | Average per Haul. |
|---|---|---|---|
| Aug. 27 | 9·5 c.c. | Sept. 20 | 5 c.c. |
| ,, 28 | 3 ,, | ,, 21 | 4·5 ,, |
| ,, 29 | 8 ,, | ,, 23 | 8·5 ,, |
| ,, 30 | 2 ,, | ,, 24 | 8 ,, |
| ,, 31 | 2 ,, | ,, 26 | 3 ,, |
| Sept. 2 | 3 ,, | ,, 27 | 3 ,, |
| ,, 3 | 2 ,, | ,, 28 | 7 ,, |
| ,, 4 | 2 ,, | ,, 30 | 6 ,, |
| ,, 5 | 1·5 ,, | Oct. 1 | 1·5 ,, |
| ,, 6 | 2 ,, | ,, 9 | 7 ,, |
| ,, 9 | 6 ,, | ,, 14 | 11·5 ,, |
| ,, 10 | 2 ,, | ,, 24 | 7 ,, |
| ,, 11 | 2·5 ,, | Nov. 4 | 11 ,, |
| ,, 12 | 4 ,, | ,, 8 | 6 ,, |
| ,, 13 | 3 ,, | ,, 16 | 1·5 ,, |
| ,, 14 | 4·5 ,, | ,, 25 | 2·5 ,, |
| ,, 16 | 8 ,, | Dec. 12 | 1 ,, |
| ,, 17 | 4 ,, | ,, 20 | 1 ,, |
| ,, 18 | 7 ,, | ,, 23 | 1 ,, |
| ,, 19 | 7 ,, | ,, 30 | 1·5 ,, |

From this list and the unsmoothed curve shown below (fig. 8) it is seen that the greatest bulk of plankton in the water is in April, when the total catches in the day reached an average of 51 c.c. per haul. Other lesser elevations are seen in June with 20 c.c., and August with 25 c.c.

The catch in some individual hauls runs a great deal higher than these averages, the top score being the Nansen net on April 4th, with 164·5 c.c.

The spring maximum in the amount of the plankton is clearly due to a great and sudden increase in the amount of Diatoms present. The other rises seen later in the year, as in June, August, and to a slighter extent in October, are less marked, and are less clearly due to one cause.

### Seasonal Variations in the Plankton.

The above remarks indicate, what has in fact long been recognised, that the amount of plankton varies to some extent with the season.

We shall now reproduce some of our Forms giving the

results of hauls showing special features of the plankton at different times of the year.

Form No. **10**, representing the hauls taken on an off-shore station on April 5th, shows the condition of affairs during the spring maximum of Diatoms. It will be noticed that 14 millions of one species, *Chaetoceros contortum*, were present in one haul of the Nansen net. The total number of Diatoms in that haul was nearly 17 millions, including two millions of *Thalassiosira nordenskioldii*.

Comparatively few Copepoda and other large organisms were present. It will be noticed that the two surface gatherings of this date were moderately alike, the same organisms were present in both, although one net had, in some cases, about twice as many as the other; but still the hauls were of the same general type and the quantities were, in most cases, not very different, showing that one can get a good general idea of the fauna by such hauls, but that one cannot depend upon their being minutely representative. They may represent, apparently, something like double or half the quantity of organisms obtained in neighbouring hauls.

For comparison with Form **10** we print Form **71**, showing a similar series of hauls taken late in August from a neighbouring station. Here there are practically no Diatoms present, there being only a very few individuals of *Biddulphia mobiliensis*. On the other hand, the Copepoda are more abundant than they were in April. For example, compare *Oithona similis*, where only tens, amounting at most to a few hundreds, were present in April, and thousands (reaching eleven thousand in the weighted net) were in the August haul. Other interesting differences will be noticed on comparing the two Forms.

## 10.—Off-shore Station II, April 5th, 1907

| Net used | Surface. | Surface. | Hensen. | Nansen. | Weight. |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. | 9 | 12 | 12·5 | 100 | 15·5 |
| Asterionella bleakeleyi | — | — | — | 15,000 | — |
| Biddulphia mobiliensis | 3,000 | 4,000 | 1,000 | 15,000 | 7,000 |
| Chætoceros contortum | 33,000 | 78,000 | 286,000 | 14,000,000 | 160,000 |
| ,, decipiens | 6,000 | 6,000 | 6,000 | 50,000 | 10,000 |
| ,, teres | — | — | 2,000 | 50,000 | — |
| ,, diadema | — | — | 1,000 | — | — |
| Coscinodiscus concinnus | 2,000 | 4,000 | 1,000 | 15,000 | 2,000 |
| Coscinosira polychorda | — | — | 4,000 | — | — |
| Rhizosolenia semispina | 1,000 | 2,000 | 4,000 | — | — |
| Thalassiosira gravida | 1,000 | 1,000 | 8,000 | 90,000 | — |
| ,, nordenskioldii | 21,000 | 52,000 | 26,000 | 2,000,000 | 70,000 |
| Lauderia borealis | 1,000 | 2,000 | 20,000 | 600,000 | 8,000 |
| Ceratulina bergonii | — | — | 1,000 | — | — |
| Ceratium furca | — | 1,000 | 1,000 | — | 2,000 |
| ,, fusus | 1,000 | 3,000 | 1,000 | — | 1,000 |
| ,, tripos | 1,500 | 3,000 | 1,000 | — | 1,000 |
| Medusoid gonophores | 40 | 20 | — | — | 90 |
| Plutei of Echinoderms | 500 | 1,000 | — | — | 1,000 |
| Sagitta bipunctata | — | — | — | — | 6 |
| Larval Polychæta | — | — | 4 | — | — |
| "Mitraria" | — | — | — | — | 500 |
| Crab zoea | — | — | 1 | 6 | 5 |
| Mysis stage of Crangon | — | — | — | — | 1 |
| Larval Nephrops 1st stage | — | — | — | — | 3 |
| Evadne nordmanni | 15 | 10 | — | — | — |
| Calanus helgolandicus | — | — | — | — | 10 |
| Pseudocalanus elongatus | 35 | 40 | 16 | 250 | 220 |
| Temora longicornis | 10 | 30 | 3 | 225 | 130 |
| Centropages hamatus | 25 | 40 | — | — | — |
| Anomalocera pattersoni | 50 | 40 | — | — | 10 |
| Acartia clausi | 200 | 220 | 6 | 300 | 110 |
| Oithona similis | 20 | 10 | 7 | 200 | 30 |
| Copepod nauplii | 1,000 | 2,000 | 9,000 | — | 6,000 |
| ,, metanauplii | 30 | 20 | — | — | — |
| Barnacle nauplii | 10 | 15 | 2 | 2 | — |
| Oikopleura sp. | 300 | 225 | 12 | 1,500 | 520 |
| Fish eggs: Rockling | — | 2 | — | — | 2 |
| ,, Scald fish | 6 | 1 | 1 | 1 | 1 |
| ,, Plaice | 1 | — | — | — | — |
| ,, Flounder | 2 | — | — | — | — |
| ,, Long Rough Dab | — | 1 | — | — | — |
| ,, Dab | — | 3 | — | — | — |
| ,, Sail Fluke | — | 2 | — | — | — |
| ,, Whiting | 11 | 14 | — | 4 | 5 |
| ,, Haddock | 2 | — | — | 1 | 2 |
| ,, Green Cod | 5 | 6 | — | 5 | 5 |
| ,, Cod | 13 | 12 | — | 4 | 2 |
| ,, Bib | — | 3 | — | 1 | — |
| Young fishes, Plaice | — | — | 1 | — | — |

## 71.—Off-shore Station I, Aug. 21st, 1907.

| ›t used | Surface | Surface | Hensen | Nansen | Nansen | Weight |
|---|---|---|---|---|---|---|
| ›pth in fathoms | 0 | 0 | 20-10 | 20-0 | 20-10 | 10-0 |
| tch in c.cm. | 1·5 | 7 | 0·5 | 2·5 | 2 | 8·5 |
| ddulphia mobiliensis | — | — | — | 25 | — | — |
| ratium furca | — | — | 10 | — | — | — |
| ,, fusus | — | — | 80 | 25 | 50 | |
| ,, tripos | 250 | 1,500 | 700 | 100 | 600 | 1,300 |
| ridinium sp. | — | — | 30 | 50 | 25 | — |
| ochiscia sp. | — | — | 10 | — | — | — |
| gitta bipunctata | 12 | 14 | 3 | 30 | 10 | 25 |
| mopteris onisciformis | — | — | 3 | — | — | — |
| rval Polychæta | 100 | 100 | — | — | — | — |
| ab zoea | — | 3 | 1 | — | 1 | 1 |
| , megalopa | — | — | — | — | — | 1 |
| ›sis stage of Crangon | 1 | — | 1 | 3 | 6 | 10 |
| rydice inermis | — | 1 | — | — | — | — |
| phrops 1st stage | — | — | 1 | — | 2 | — |
| don intermedium | 10 | 40 | — | 20 | 10 | 50 |
| adne nordmanni | — | — | — | — | — | 15 |
| lanus helgolandicus | 100 | 200 | 2 | 10 | 8 | 125 |
| ›udocalanus elongatus | 60 | 30 | 50 | 300 | 375 | 550 |
| mora longicornis | 25 | 40 | 5 | 65 | 40 | 100 |
| ıtropages hamatus | 80 | 75 | 5 | 5 | — | 80 |
| omalocera pattersoni | 7 | 15 | — | — | — | 4 |
| artia clausi | 320 | 800 | — | 110 | 55 | 750 |
| ›hona similis | 2,200 | 8,000 | 125 | 1,000 | 500 | 11,000 |
| rapontella | 6 | 10 | — | 5 | — | — |
| aumaleus rigidus | — | — | — | — | 1 | — |
| pepod nauplii | 10,000 | 30,000 | 750 | 2,000 | 1,350 | 15,000 |
| ,, juv. | 2,600 | 5,000 | 240 | 500 | 500 | 2,000 |
| steropods, larval | — | — | — | 25 | — | — |
| mellibranchs, larval | — | — | 10 | 50 | 25 | — |
| topleura sp. | 360 | 200 | 6 | 500 | — | 200 |
| h eggs, Goldsinny | 1 | — | — | — | — | — |

In Form **66** we give the results of four hauls taken in Port Erin Bay about the middle of August (14th to 17th) to show again a plankton where Diatoms were absent, but where Copepods were present in abundance, amounting to 25,000 in the case of *Oithona similis* on August 17th. The three hauls of August 14th, 15th and 16th are very similar in total amounts, and not unlike in some of the constituent items, but the haul on August 17th showed nearly double the total quantity, due mainly

to the increase in one species of Copepod—*Oithona similis.* August 14th showed an unusually large number of Copepod Nauplii and of *Oikopleura.*

**66.**—Port Erin Bay. August 14, 15th, 16th, 17th.

| | | | | |
|---|---|---|---|---|
| Depth in Fathoms | 0 | 0 | 0 | 0 |
| Catch in c.cm. | 18 | 18·5 | 17·5 | 30·5 |
| Ceratium tripos | 1,000 | 1,000 | 500 | — |
| Pleurobrachia pileus | — | 1 | 3 | — |
| Medusoid gonophores | 250 | 2 | 100 | — |
| Sagitta bipunctata | 600 | 1,800 | 800 | 700 |
| Tomopteris onisciformis | — | 25 | 6 | — |
| "Mitraria" | 100 | — | — | — |
| Crab zoea | 200 | 300 | — | 5 |
| „ megalopa | — | 3 | — | 20 |
| Mysis stage of Crangon | 200 | 200 | 2 | 15 |
| Podon intermedium | 300 | — | 100 | 200 |
| Evadne nordmanni | 100 | — | — | — |
| Calanus helgolandicus | 50 | 700 | 500 | 700 |
| Pseudocalanus elongatus | 3,500 | 700 | 500 | 800 |
| Temora longicornis | 3,500 | 6,500 | 2,500 | 2,000 |
| Centropages hamatus | 100 | 200 | 200 | 200 |
| Acartia clausi | 1,000 | 600 | 100 | 200 |
| Oithona similis | 12,000 | 6,000 | 5,000 | 25,000 |
| Caligus rapax | — | — | 1 | — |
| Paracalanus parvus | 250 | — | — | — |
| Copepod nauplii | 25,000 | 13,000 | 3,500 | 13,000 |
| „ juv. | 4,000 | 4,000 | 3,500 | 5,000 |
| Lamellibranchs, larval | 1,500 | — | — | — |
| Oikopleura sp. | 2,800 | 900 | 200 | 200 |
| Fish eggs, Rockling | 15 | 1 | 40 | 25 |
| „ Brill | — | — | — | 1 |
| „ Goldsinny | — | 1 | — | — |

In Form **104** we show an example of the Diatom fauna that makes its appearance again late in September. The two surface nets represented show very large numbers of Diatoms, extending up to 13 millions and 16 millions in single hauls in the case of *Rhizosolenia semispina*—in fact this highest peak in the September maximum of Diatoms is mainly composed of this one species of *Rhizosolenia*, whereas in the spring maximum the bulk of the catch, as may be seen from Form **10** (p. 108), is made up of *Chaetoceros contortum* and *Thalassiosira*

*nordenskioldii*, species that are rare or altogether absent in September gatherings. The genus *Thalassiosira* is mainly a spring form, rarely present after May, and is not represented in autumn in this year's results.

**104**.—Station III, September 12.

| | | |
|---|---|---|
| Depth in fathoms ..... | 0 | 0 |
| Catch in c.cm. ..... | 10½ | 11 |
| Asterionella bleakeleyi ..... | 1,200 | 1,200 |
| Chaetoceros debile ..... | 1,000 | 3,000 |
| ,, decipiens ..... | 7,500 | 8,000 |
| ,, teres ..... | 20,000 | 60,000 |
| ,, subtile ..... | 123,000 | 140,000 |
| Coscinodiscus concinnus ... | 2,500 | 2,500 |
| Ditylium brightwellii ..... | 2,500 | 2,500 |
| Eucampia zodiacus ..... | 3,750 | 4,000 |
| Melosira borreri ..... | 4,000 | 5,000 |
| Lauderia borealis ..... | 100,000 | 120,000 |
| Leptocylindrus sp..... | 38,000 | 50,000 |
| Coscinodiscus radiatus ..... | 1,250 | 1,250 |
| Rhizosolenia semispina ..... | 13,000,000 | 16,000,000 |
| ,, shrubsolei ..... | 15,000 | 20,000 |
| ,, stolterfothii ... | 25,000 | 30,000 |
| ,, setigera ..... | 2,500 | 2,500 |
| ,, alata ..... | 140,000 | 150,000 |
| Ceratium furca ..... | 2,500 | 7,500 |
| ,, fusus ..... | 15,000 | 17,000 |
| ,, tripos ..... | 37,000 | 50,000 |
| Medusoid gonophores ..... | 2 | 7 |
| Calanus helgolandicus ..... | 5 | 11 |
| Pseudocalanus elongatus ... | 40 | 60 |
| Centropages hamatus ..... | 8 | 20 |
| Acartia clausi ..... | 800 | 900 |
| Oithona similis ..... | 200 | 250 |
| Isias clavipes ..... | 8 | 5 |
| Parapontella brevicornis ..... | 1 | 1 |
| Paracalanus parvus ..... | 20 | 80 |
| Copepod nauplii..... | 8,000 | 9,000 |
| ,, juv..... | 3,000 | 3,800 |
| Oikopleura sp. ..... | 10 | 10 |
| Ascidian eggs ..... | 4,000 | 10,000 |

The three seasonal conditions illustrated by Forms **10** (April), **66** and **71** (August), and **104** (September) are very well marked, and a detailed examination of these series of hauls is instructive.

## COMPARISON OF HAULS.

The results which we print (Forms **17** and **18**) of the hauls obtained on April 9th and 10th in Port Erin Bay are good examples of a local plankton mainly composed of Diatoms. It will be noticed in running the eye down the groups in Form **17** that whereas the Diatoms occur in thousands extending up to even 100,000, the Dinoflagellates are in hundreds, extending, at most, to a thousand; the Copepoda are in tens, rarely reaching a hundred or two, while the fish-eggs are scattered units, such as 1 and 2. The general character of these hauls on April 9th, then, is that there are ten times as many Copepods as fish-eggs; ten times as many Dinoflagellates as Copepods, and ten times as many Diatoms as Dinoflagellates, per species. In Form **18**, on the following day, the proportions are somewhat the same; and if we pick out the largest numbers recorded in each of these groups they may be described in the case of each day as units, hundreds, thousands and tens of thousands.

| | Diatoms | Dinoflagellates | Copepods | Fish Eggs |
|---|---|---|---|---|
| April 9 | 100,000 | 1,000 | 250 | 2 |
| April 10 | 90,000 | 2,000 | 780 | 8 |

As another example of the same run of figures in these groups we note that in a surface haul, W. of the Calf Island, on March 29th, the total

| | |
|---|---|
| Diatoms amount to ... ... ... | 72,650 |
| Dinoflagellates ,, ... ... ... | 3,500 |
| Copepoda ,, ... ... ... | 363 |
| Fish Eggs ,, ... ... ... | 93 |

Generally speaking these proportions hold good for many of the series of hauls not only in the Bay, but also outside; see, for example, Forms **20** and **21**, below.

It is also interesting to note that of these two series of hauls taken in exactly the same spot on adjoining days,

the total amount obtained is much the same, but is made up of rather different constituents, *Biddulphia mobiliensis*, *Chaetoceros contortum*, and some other forms, being more abundant on the 9th; while *C. debile*, present on the 9th, is altogether absent on the 10th. The very large number of Echinoderm Plutei on April 9th is noteworthy; their occurrence is very sporadic; they were present again in large numbers on April 19th, when 1,000 were taken in the haul corresponding to I. A. on April 9th. But, on the whole, the resemblance between the two hauls is more striking than the differences, the list of organisms is very nearly identical in the two sheets, and the general run of the numbers is for the most part the same.

Another interesting comparison, in this case of two separate but not distant localities taken practically at the same time, is seen in the Forms (**20** and **21**) that are given here for April 10th. No. **20** is from off-shore station I, five miles N.W. of Bradda Head, while No. **21** is from the second station ten miles off land along the same line. Both are in the open sea and at both the same set of nets (Hensen, Nansen, Weighted, and two Surface nets) were used, within an hour; but in the first locality the total bulk of the plankton caught was 104 c.c. while in the second locality it was only 39 c.c.; and it will be noticed in running the eye down the figures for the different organisms that the five-mile station yielded far more in the case of Diatoms and Dinoflagellates and fish-eggs, but less in the case of Copepoda. The total Diatoms amount to over $3\frac{1}{2}$ millions at five miles as against 324,000 at ten miles; the total Dinoflagellates is 55,000 at five miles and 13,000 at ten miles; while the Copepods are under 3,000 at five miles and nearly 5,000 at ten miles. The general run of organisms present is the same in the two cases, although the total numbers differ so much.

## 17.—Port Erin Bay, April 9th, 1907.

| Net used, Surface ..... | I.A | II.A | I.B1 | I.B2 | I.B3 | II.B1 | II.B2 |
|---|---|---|---|---|---|---|---|
| Catch in c.cm. ..... | 10·5 | 8 | 7 | 6·5 | 4 | 8·5 | 8·5 |
| Biddulphia mobiliensis | 45,000 | 7,000 | 8,500 | 2,500 | 3,000 | 7,500 | 2,500 |
| Chaetoceros contortum... | 39,000 | 38,000 | 70,000 | 31,000 | 50,000 | 100,000 | 50,000 |
| ,, debile ..... | 9,000 | — | 2,000 | — | 2,500 | 2,000 | — |
| ,, decipiens ... | 7,500 | 3,500 | 8,500 | 4,000 | 2,500 | 5,500 | 3,500 |
| ,, teres ..... | 1,500 | — | 1,000 | — | 1,000 | — | 500 |
| ,, diadema ... | 2,000 | — | 2,500 | 1,000 | 1,000 | 500 | 1,500 |
| ,, criophilum | — | — | — | — | — | 500 | — |
| Coscinodiscus concinnus | 3,000 | 2,000 | 2,000 | 1,000 | 2,000 | 3,500 | — |
| Ditylium brightwellii ... | — | — | 500 | — | 250 | 1,000 | — |
| Rhizosolenia semispina... | 500 | 1,000 | 1,000 | 2,000 | 1,000 | 3,000 | 1,700 |
| Thalassiosira gravida ... | 100 | 100 | — | — | 250 | 500 | 500 |
| ,, nordenskioldii | 12,000 | 13,000 | 5,000 | 14,000 | 11,000 | 30,000 | 17,000 |
| ,, subtilis ..... | 1,000 | 6,000 | 6,000 | 4,000 | 5,000 | 5,500 | 4,000 |
| Lauderia borealis ..... | 2,500 | 500 | 2,500 | 500 | 500 | 3,000 | 750 |
| Trochiscia sp..... | — | — | — | — | 20 | 25 | 25 |
| Acanthometra sp..... | — | — | — | — | 50 | 50 | — |
| Ceratium furca ..... | 300 | — | 500 | — | 250 | 200 | 500 |
| ,, fusus ..... | 100 | 1,000 | 500 | 1,000 | 500 | 1,000 | 1,000 |
| ,, tripos ..... | — | 1,000 | 500 | — | 500 | 250 | 500 |
| Peridinium sp. ..... | — | 1,000 | 500 | 100 | 250 | 300 | 500 |
| Medusoid gonophores ... | 75 | 70 | 10 | 27 | 30 | 30 | 20 |
| Plutei of Echinoderms | 1,000 | 1,500 | 500 | 500 | 500 | — | — |
| Larval Polychaeta..... | 75 | 75 | 20 | 10 | 30 | 50 | 30 |
| "Mitraria" ..... | 100 | 100 | — | — | 100 | 100 | 100 |
| Crab zoea ..... | 5 | — | — | 1 | — | 1 | — |
| Podon intermedium ..... | 20 | 12 | 10 | 10 | 20 | — | 10 |
| Evadne nordmanni ..... | 5 | — | — | — | — | 50 | — |
| Calanus helgolandicus ... | 25 | 6 | 10 | 10 | 10 | 15 | 10 |
| Pseudocalanus elongatus | 70 | 175 | 150 | 250 | 190 | 125 | 140 |
| Temora longicornis ..... | 20 | 35 | 20 | 5 | 5 | 45 | 20 |
| Centropages hamatus ... | — | — | 5 | 5 | 5 | 10 | 10 |
| Acartia clausi ..... | 60 | 40 | 10 | 40 | 15 | 60 | 45 |
| Oithona similis ..... | 140 | 85 | 55 | 40 | 35 | 100 | 70 |
| Anomalocera juv. ..... | — | 2 | — | — | 10 | — | — |
| Paracalanus parvus ..... | — | — | — | 15 | — | — | — |
| Copepod nauplii ..... | 11,000 | 3,000 | 3,000 | 1,500 | 4,500 | 3,000 | 2,000 |
| ,, metanauplii ... | — | 20 | — | — | — | — | — |
| ,, juv. ..... | 1,100 | 375 | 160 | 475 | 165 | 400 | 300 |
| Barnacle nauplii ..... | 400 | 175 | 75 | 275 | 220 | 140 | 180 |
| ,, cypris stage ... | 10 | 6 | 6 | 12 | 7 | 5 | 1 |
| Oikopleura sp. ..... | 900 | 600 | 550 | 700 | 630 | 750 | 680 |
| Fish Eggs:—Rockling... | 1 | 1 | — | 2 | — | — | — |
| Com. Dragonet ..... | 2 | 1 | — | — | 1 | — | — |
| Cod ..... | 1 | 1 | — | — | — | — | — |
| Green Cod ..... | 1 | — | — | — | — | 2 | — |
| Bib ..... | 1 | — | — | — | — | — | — |
| Whiting ..... | 2 | — | — | 1 | — | 1 | 1 |
| Red Gurnard ..... | — | 1 | — | — | — | — | — |
| Topknot..... | 2 | — | — | — | — | — | — |
| Dab ..... | 1 | 1 | — | — | — | — | — |
| Sail Fluke ..... | 1 | — | — | — | — | — | — |
| Sprat ..... | — | 1 | — | 1 | — | 1 | — |
| Young Fishes— | | | | | | | |
| Larval Gadoid ..... | — | — | 1 | — | — | — | — |
| *Larval* Pleuronectid ... | — | — | — | — | — | 1 | — |

## 18.—Port Erin Bay, April 10th, 1907.

| Net used, Surface ..... | I.A1 | II.A | I.B1 | I.B2 | I.B3 | II.B1 | II.B2 |
|---|---|---|---|---|---|---|---|
| Catch in c.cm. ..... | 14 | 8 | 7 | 8 | 8 | 10·5 | 12·5 |
| Biddulphia mobiliensis | 5,000 | 1,500 | 1,500 | 500 | 3,000 | 1,500 | 4,000 |
| Chaetoceros contortum | 15,000 | 20,000 | 20,000 | 15,000 | 50,000 | 90,000 | 20,000 |
| ,, decipiens ... | 2,000 | — | 1,000 | 2,000 | 5,000 | 6,000 | — |
| ,, teres ..... | — | — | 500 | 500 | 500 | 500 | — |
| ,, diadema ... | — | 150 | — | — | 1,500 | 500 | — |
| Coscinodiscus concinnus | 2,000 | 1,000 | 1,500 | 500 | 2,000 | 500 | 1,000 |
| Eucampia zodiacus ..... | — | — | — | — | 200 | — | — |
| Rhizosolenia semispina | 500 | — | 500 | 500 | 3,500 | 1,000 | 1,000 |
| Thalassiosira gravida ... | — | — | — | — | 500 | 500 | — |
| ,, nordenskioldii | 3,500 | 10,000 | 4,000 | 4,000 | 32,000 | 28,000 | 6,000 |
| ,, subtilis..... | 8,000 | 6,000 | 3,000 | 2,000 | 6,000 | 9,000 | 4,000 |
| Lauderia borealis ..... | 500 | 250 | — | 500 | 4,000 | 1,000 | 500 |
| Trochiscia, sp. ..... | — | 50 | — | — | — | — | — |
| Acanthometra sp..... | 30 | — | 150 | — | 50 | 25 | — |
| Ceratium furca ..... | — | — | 100 | — | 250 | 250 | 150 |
| ,, fusus ..... | 1,500 | 250 | 500 | — | 250 | 500 | 200 |
| ,, tripos ..... | 200 | 500 | 2,000 | — | 250 | 500 | 250 |
| Peridinium sp. ..... | 500 | 100 | 500 | 500 | 500 | 1,000 | 150 |
| Medusoid gonophores ... | 150 | 3 | 60 | 70 | 50 | 15 | 180 |
| Plutei of Echinoderms | 100 | 100 | — | — | 250 | 500 | — |
| Sagitta bipunctata ..... | — | — | — | — | — | 2 | — |
| Larval Polychaeta ..... | 150 | 5 | 60 | — | 50 | — | 120 |
| "Mitraria" ..... | 200 | 150 | 50 | — | 100 | — | 200 |
| Crab zoea ..... | — | — | — | — | 1 | — | 5 |
| Mysis stage of Crangon | 5 | — | 3 | — | 1 | — | — |
| Podon intermedium ..... | 20 | — | 10 | 30 | — | — | 15 |
| Evadne nordmanni ..... | 10 | 2 | 20 | 20 | 10 | — | 15 |
| Calanus helgolandicus ... | 60 | 30 | 100 | 30 | 35 | — | 60 |
| Pseudocalanus elongatus | 780 | 30 | 300 | 150 | 50 | 35 | 480 |
| Temora longicornis ..... | 100 | 30 | 70 | 50 | 60 | 35 | 100 |
| Centropages hamatus ... | 20 | 10 | 30 | 4 | 10 | — | 15 |
| Acartia clausi ..... | 70 | 30 | 80 | 50 | 150 | 30 | 90 |
| Oithona similis ..... | 350 | 100 | 200 | 100 | 250 | 300 | 200 |
| Anomalocera juv. ..... | — | 10 | 10 | — | — | 25 | — |
| Paracalanus parvus ..... | — | — | — | — | — | — | 60 |
| Copepod nauplii..... | 11,500 | 500 | 2,500 | 3,500 | 500 | 1,000 | 12,000 |
| ,, juv..... | 2,250 | 75 | 750 | 900 | 350 | 100 | 2,000 |
| Barnacle nauplii ..... | 850 | 50 | 460 | 270 | 150 | 10 | 1,230 |
| ,, cypris stage | 12 | 4 | 8 | 10 | 2 | 1 | 10 |
| Oikopleura sp. ..... | 1,800 | 250 | 1,300 | 950 | 700 | 230 | 2,000 |
| Fish Eggs—Rockling ... | 1 | 6 | — | — | 1 | 8 | — |
| Common Dragonet ... | — | — | 1 | — | — | 1 | |
| Cod ..... | 1 | — | — | — | 1 | 1 | 1 |
| Green cod ..... | — | 2 | 1 | — | 1 | 1 | — |
| Bib ..... | 1 | 1 | — | 1 | 3 | — | — |
| Whiting ..... | 2 | — | — | — | — | 3 | — |
| Flounder ..... | — | — | — | — | — | 3 | — |
| Dab ..... | — | — | — | — | — | 1 | — |
| Long rough dab ..... | — | — | — | — | — | — | 1 |
| Sail fluke ..... | — | — | — | — | — | — | 1 |
| Sprat ..... | — | — | — | — | 1 | — | — |
| Young Fishes— | | | | | | | |
| Pleuronectid ..... | 1 | — | — | — | — | — | — |

## 20.—Off-shore Station I, April 10th, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. | 12 | 18·5 | 1 | 58·5 | 15 |
| Biddulphia mobiliensis | 5,000 | 5,000 | 500 | 1,000 | 7,000 |
| Chaetoceros contortum | 39,000 | 28,000 | 19,000 | 1,200,000 | 26,000 |
| ,, debile | — | — | — | 75,000 | — |
| ,, decipiens | 2,000 | 1,000 | 500 | 62,000 | 2,000 |
| ,, sociale | — | — | 4,500 | 75,000 | — |
| ,, teres | — | — | 1,000 | 25,000 | 1,000 |
| ,, diadema | — | — | — | 25,000 | — |
| Coscinodiscus concinnus | 1,000 | 1,500 | 500 | 12,000 | 1,000 |
| Ditylium brightwellii | — | — | — | 6,000 | — |
| Eucampia zodiacus | — | 150 | — | — | — |
| Rhizosolenia semispina | 1,000 | — | — | 12,000 | 1,000 |
| Thalassiosira gravida | — | — | 500 | 12,000 | — |
| ,, nordenskioldii | 58,000 | 135,000 | 15,000 | 1,600,000 | 17,000 |
| ,, subtilis | 3,000 | 1,500 | — | 12,000 | 10,000 |
| Lauderia borealis | 1,000 | 1,500 | 5,000 | 150,000 | — |
| Ceratium furca | — | 1,000 | — | — | — |
| ,, fusus | 3,000 | 500 | — | — | 1,000 |
| ,, tripos | 4,000 | 3,000 | 500 | — | 3,000 |
| Peridinium sp. | 1,000 | 1,000 | — | 37,000 | 500 |
| Medusoid gonophores | 30 | 80 | 5 | 26 | 80 |
| Plutei of Echinoderms | 1,000 | 1,000 | — | — | 500 |
| Sagitta bipunctata | — | — | — | — | 6 |
| Tomopteris onisciformis | — | — | — | 1 | 2 |
| Larval Polychaeta | — | — | — | 20 | 20 |
| Crab zoea | 2 | 1 | — | — | 6 |
| Mysis stage of Crangon | — | — | — | 1 | 14 |
| Nephrops, 1st stage | — | — | — | 3 | 5 |
| Podon intermedium | — | — | 1 | — | 10 |
| Evadne nordmanni | 10 | 10 | — | — | 10 |
| Calanus helgolandicus | 25 | 1 | 3 | 23 | 20 |
| Pseudocalanus elongatus | — | — | 18 | 130 | 350 |
| Temora longicornis | 25 | — | 5 | 56 | 180 |
| Centropages hamatus | 30 | 40 | — | 2 | 10 |
| Acartia clausi | 500 | 500 | 8 | 14 | 200 |
| Oithona similis | — | 30 | 2 | 47 | 40 |
| Anomalocera juv. | 170 | 500 | — | — | 20 |
| Copepod nauplii | 3,000 | 2,000 | 500 | — | 5,000 |
| ,, metanauplii | — | — | — | — | 100 |
| ,, juv. | 500 | — | 25 | 130 | 600 |
| Barnacle nauplii | 10 | 10 | 2 | 25 | 20 |
| ,, cypris stage | 2 | 1 | — | 1 | 5 |
| Oikopleura sp. | 270 | 300 | 18 | 80 | 350 |
| Fish Eggs: Haddock | 4 | — | — | — | 1 |
| Cod | 5 | 31 | — | — | 5 |
| Green Cod | 15 | 33 | — | — | 22 |
| Com. Dragonet | 5 | 3 | — | — | 1 |
| Whiting | 60 | 89 | — | — | 16 |
| Rockling | — | 1 | — | — | — |
| Grey Gurnard | — | 6 | — | — | — |
| Bib | 3 | 23 | — | — | 6 |
| Topknot | 1 | 3 | — | — | 1 |
| Brill | 1 | — | — | — | — |
| Red Gurnard | 1 | — | — | — | — |
| Sail Fluke | 9 | 2 | — | — | 1 |
| Dab | 2 | 4 | — | — | 1 |
| Scald fish | 3 | 1 | — | — | — |
| Long Rough Dab | — | 1 | — | — | 1 |
| Sprat | 3 | 6 | — | — | 4 |
| Young fishes—Gadoid | — | — | — | 1 | 10 |

## 21. Off-shore Station II, April 10th, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. | 7 | 8·5 | 2·5 | 9 | 12 |
| Asterionella bleakeleyi | — | — | 100 | — | — |
| Biddulphia mobiliensis | 100 | 100 | 100 | 250 | — |
| Chaetoceros contortum | 1,000 | 4,000 | 12,000 | 180,000 | 2,000 |
| ,, decipiens | — | — | 2,000 | 11,000 | — |
| ,, sociale | — | — | 100 | 5,000 | — |
| ,, teres | — | — | — | 4,000 | — |
| Coscinodiscus concinnus | 2,000 | 1,000 | 100 | 1,000 | 1,000 |
| Ditylium brightwellii | — | — | — | 1,000 | — |
| Eucampia zodiacus | — | — | — | 500 | — |
| Rhizosolenia semispina | — | — | 100 | 1,000 | — |
| ,, stolterfothii | — | — | — | 100 | — |
| Thalassiosira gravida | — | — | 50 | 1,000 | — |
| ,, nordenskioldii | 1,500 | 3,500 | 10,000 | 58,000 | 1,000 |
| ,, subtilis | 1,000 | — | 50 | 5,000 | 2,000 |
| Lauderia borealis | 100 | — | 1,500 | 9,000 | — |
| Ceratulina bergonii | — | — | — | 250 | — |
| Ceratium furca | 500 | 100 | 1,000 | — | — |
| ,, fusus | 200 | 500 | 500 | — | — |
| ,, tripos | 1,000 | 500 | 500 | 1,000 | 1,000 |
| Peridinium sp. | 500 | 1,000 | 500 | 3,000 | 2,000 |
| Medusoid gonophores | 40 | 10 | — | 16 | 150 |
| Plutei of Echinoderms | — | — | 100 | 500 | 1,000 |
| Sagitta bipunctata | — | — | — | 6 | 24 |
| Tomopteris onisciformis | — | — | — | 1 | 2 |
| Larval Polychaeta | — | — | — | 20 | — |
| "Mitraria" | 150 | — | 50 | — | 1,000 |
| Mysis stage of Crangon | — | — | — | 5 | 6 |
| Podon intermedium | — | — | 1 | — | — |
| Evadne nordmanni | 10 | — | — | — | — |
| Calanus helgolandicus | 6 | 2 | 3 | 36 | 150 |
| Pseudocalanus elongatus | — | — | 3 | 240 | 450 |
| Temora longicornis | 10 | 30 | 4 | 30 | 200 |
| Centropages hamatus | 10 | 10 | — | — | |
| Acartia clausi | 880 | 570 | 2 | 15 | 62 |
| Oithona similis | 30 | 100 | 2 | 115 | 375 |
| Anomalocera juv. | 500 | 750 | — | — | 400 |
| Copepod nauplii | 1,500 | 2,000 | 1,000 | 3,000 | 5,000 |
| ,, metanauplii | 36 | 150 | — | 20 | 350 |
| ,, juv. | 360 | 500 | 10 | 500 | 250 |
| Barnacle nauplii | 10 | 40 | 5 | 60 | 330 |
| ,, cypris stage | 3 | 5 | 1 | 3 | 25 |
| Oikopleura sp. | 1,360 | 1,800 | 22 | 400 | 1,000 |
| Fish Eggs— | | | | | |
| Whiting | 16 | 13 | — | — | — |
| Red Gurnard | 8 | 5 | — | — | 1 |
| Green Cod | 12 | 7 | — | — | 1 |
| Cod | — | 6 | — | — | 1 |
| Bib | 2 | — | — | — | — |
| Scald fish | 1 | 1 | 3 | 2 | 5 |
| Dab | 3 | 1 | — | — | — |
| Sprat | — | — | — | 1 | — |
| Young fishes—Gadoid | — | — | — | — | 5 |

As representative examples of the series of hauls taken at the two offshore stations (I and II) early in April we give here copies of our Forms **10** and **12**. These are both localities in the open sea, well out from the land, about five miles apart, and under, so far as can be seen, practically the same influences and conditions. They exemplify several points we wish to elaborate, viz., a certain amount of similarity between the surface hauls, the weighted net at ten fathoms showing as a rule a larger catch than the surface nets, and the Nansen vertical bringing up more than the Hensen. But the point we specially wish to illustrate from these Forms is that the plankton fauna on these two occasions had a similar character, although the numerical results may be far from agreeing. The total Diatoms at Station I are over twelve millions and at Station II over seventeen; in each case it is the Nansen net that caught the millions both of *Chaetoceros* and of *Thalassiosira*. The total Copepoda at Station I is 1,534 and at Station II 2,247, but the numbers in the case of some of the species are of the same "order" on the two Forms—*Calanus* is in units, *Centropages* and *Anomalocera* in tens and *Acartia* in hundreds in each case.

Finally, the conclusion one comes to from the inspection of these Forms is that much the same organisms are present in somewhat similar proportions; so that although it is possible to discuss the general character of the fauna and the relative abundance of different groups, it is not possible to use the numbers as the basis of calculations as to the quantity of any group, or of living things as a whole, in any large area of the sea at a particular time—the results arrived at might easily be 50 per cent. wrong in either direction.

To show—what will be readily admitted by all who

**10.**—Station II, April 5th, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. | 9 | 12 | 12·5 | 100 | 15·5 |
| Asterionella bleakeleyi | — | — | — | 15,000 | — |
| Biddulphia mobiliensis | 3 000 | 4,000 | 1,000 | 15,000 | 7,000 |
| Chaetoceros contortum | 33,000 | 78,000 | 286,000 | 14,000,000 | 160 000 |
| ,, decipiens | 6,000 | 6,000 | 6,000 | 50,000 | 10,000 |
| ,, teres | — | — | 2,000 | 50,000 | — |
| ,, diadema | — | — | 1,000 | — | — |
| Coscinodiscus concinnus | 2,000 | 4,000 | 1,000 | 15,000 | 2,000 |
| Coscinosira polychorda | — | — | 4,000 | — | — |
| Rhizosolenia semispina | 1,000 | 2,000 | 4,000 | — | — |
| Thalassiosira gravida | 1,000 | 1,000 | 8,000 | 90,000 | — |
| ,, nordenskioldii | 21,000 | 52,000 | 26,000 | 2,000,000 | 70,000 |
| Lauderia borealis | 1,000 | 2,000 | 20,000 | 600,000 | 8,000 |
| Ceratulina bergonii | — | — | 1,000 | — | — |
| Ceratium furca | — | 1,000 | 1,000 | — | 2,000 |
| ,, fusus | 1,000 | 3,000 | 1,000 | — | 1,000 |
| ,, tripos | 1,500 | 3,000 | 1,000 | — | 1,000 |
| Medusoid gonophores | 40 | 20 | — | — | 90 |
| Plutei of Echinoderms | 500 | 1,000 | — | — | 1,000 |
| Sagitta bipunctata | — | — | — | — | 6 |
| Larval Polychaeta | — | — | 4 | — | — |
| 'Mitraria' | — | — | — | — | 500 |
| Crab zoea | — | — | 1 | 6 | 5 |
| Mysis stage of Crangon | — | — | — | — | 1 |
| Larval Nephrops stage 1 | — | — | — | — | 3 |
| Evadne nordmanni | 15 | 10 | — | — | — |
| Calanus helgolandicus | — | — | — | — | 10 |
| Pseudocalanus elongatus | 35 | 40 | 16 | 250 | 220 |
| Temora longicornis | 10 | 30 | 3 | 225 | 130 |
| Centropages hamatus | 25 | 40 | — | — | — |
| Anomalocera pattersoni | 50 | 40 | — | — | 10 |
| Acartia clausi | 200 | 220 | 6 | 300 | 110 |
| Oithona similis | 20 | 10 | 7 | 200 | 30 |
| Copepod nauplii | 1,000 | 2,000 | 9,000 | — | 6,000 |
| ,, metanauplii | 30 | 20 | — | — | — |
| Barnacle nauplii | 10 | 15 | 2 | 2 | — |
| Oik. pleura sp. | 300 | 225 | 12 | 1,500 | 520 |
| Fish eggs:— | | | | | |
| Rockling | — | 2 | — | — | 2 |
| Scald fish | 6 | 1 | 1 | 1 | 1 |
| Plaice | 1 | — | — | — | — |
| Flounder | 2 | — | — | — | — |
| Long Rough Dab | — | 1 | — | — | — |
| Dab | — | 3 | — | — | — |
| Sailfluke | — | 2 | — | — | — |
| Whiting | 11 | 14 | — | 4 | 5 |
| Haddock | 2 | — | — | 1 | 2 |
| Green Cod | 5 | 6 | — | 5 | 5 |
| Cod | 13 | 12 | — | 4 | 2 |
| Bib | — | 3 | — | 1 | — |
| Young fishes:— | | | | | |
| Plaice | — | — | 1 | — | — |

## 12.—Station I, April 8th, 1907.

| Net used ..... | Surface | Surface | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms ..... | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. ..... | 20 | 12 | 6·5 | 73 | 21 |
| Asterionella bleakeleyi | 100 | — | — | — | — |
| Biddulphia mobiliensis | 100 | 4,000 | 300 | 20,000 | 2,000 |
| Chaetoceros contortum | 12,000 | 10,000 | 31,000 | 1,650,000 | 9,000 |
| ,, debile ..... | 156,000 | 60,000 | 100,000 | 7,500,000 | 138,000 |
| ,, decipiens ... | 9,000 | 10,000 | 4,000 | 150,000 | 27,000 |
| ,, sociale ..... | — | — | 6 000 | — | — |
| ,, teres ..... | — | — | 1,000 | — | — |
| Coscinodiscus concinnus | 800 | 3,000 | 1,000 | 50,000 | 1,000 |
| Coscinosira polychorda... | — | — | — | 20,000 | — |
| Ditylium brightwellii ... | 100 | — | — | — | — |
| Rhizosolenia semispina | 100 | — | — | — | — |
| Thalassiosira gravida ... | — | — | 1,000 | 50,000 | — |
| ,, nordenskioldii | 186,000 | 120,000 | 37,000 | 1,350,000 | 132,000 |
| ,, subtilis ... | 15,000 | 15,000 | — | — | 20,000 |
| Lauderia borealis ..... | 100 | — | 7,000 | 450,000 | 3,000 |
| Leptocylindrus danicus... | — | — | — | 1,000 | — |
| Ceratium furca ..... | 100 | 500 | — | — | 300 |
| ,, fusus ..... | 100 | 500 | — | — | 500 |
| ,, tripos ..... | 100 | 500 | 250 | — | 500 |
| Medusoid gonophores ... | — | — | — | 8 | 100 |
| Plutei of Echinoderms | — | — | — | — | 100 |
| Sagitta bipunctata ..... | — | — | — | 2 | 10 |
| Larval Polychaeta..... | — | — | 3 | 3 | 10 |
| Crab zoea ..... | 1 | — | — | — | 4 |
| Mysis stage of Crangon | — | — | 2 | 2 | — |
| Larval Nephrops, stage 1 | — | — | — | — | 2 |
| Evadne nordmanni ..... | 50 | 75 | — | — | — |
| Calanus helgolandicus ... | 1 | 2 | 1 | 3 | 1 |
| Pseudocalanus elongatus | — | — | 9 | 40 | 500 |
| Temora longicornis ..... | 10 | — | 6 | 30 | 200 |
| Centropages hamatus ... | 6 | 40 | — | — | — |
| Anomalocera pattersoni | 25 | 75 | — | — | — |
| Acartia clausi..... | 225 | 200 | 1 | — | 100 |
| Oithona similis ..... | 14 | — | 1 | 4 | 30 |
| Isias clavipes ..... | — | — | — | — | 10 |
| Copepod nauplii..... | 500 | — | 500 | 1,000 | — |
| ,, metanauplii ... | 100 | 75 | 3 | — | — |
| ,, juv. ..... | 50 | — | — | — | — |
| Barnacle nauplii ..... | 10 | 15 | 2 | 20 | 150 |
| ,, cypris stage | 10 | — | 2 | — | 4 |
| Oikopleura sp. ..... | 100 | 50 | 6 | 6 | 350 |
| Ascidian eggs ..... | — | 100 | — | — | — |
| Fish eggs :—Rockling ... | — | 1 | — | — | — |
| Common Dragonet | — | 1 | — | — | 1 |
| Sailfluke ..... | 5 | 1 | — | — | 3 |
| Topknot ..... | — | 2 | — | — | — |
| Long Rough Dab ... | 1 | — | — | — | — |
| Dab ..... | 1 | — | — | — | — |
| Scald fish ..... | 1 | — | — | — | — |
| Cod ..... | 6 | 27 | — | — | 6 |
| Whiting ..... | 29 | 47 | — | — | 10 |
| Bib ..... | 12 | 24 | — | — | — |
| Young fishes :—Gadoid... | — | — | — | 1 | — |

have had any experience of plankton work—the marked effect of the size and mesh of the net upon the resulting catch, we give here from Form **47** the hauls of two surface nets and a shear net taken off Bradda Head on April 23rd; and we add also another shear-net haul taken later the same day a couple of miles off, between Bradda Head and the Calf Island. It will be noticed that the two surface hauls are very much alike in quantity and constitution, and the two shear-net hauls are like one another and very different from the surface hauls. The shear-net has retained no Diatoms and no Dinoflagellates, but has caught far larger quantities of the larger organisms, such as Medusoids (*Hybocodon prolifer*) 4,500 against 10 and 100 taken in the surface nets at the same time, Sagitta 200 against 2, young Shrimps 1,800 against 5 and 8, and young Norway Lobsters 1,600 against 1. In the case of the Copepoda the shear-nets have large hauls of a large form such as *Calanus*, but much smaller hauls of the smaller forms such as *Acartia* and *Oithona*. Similarly the shear-nets have not retained the larval and young Copepods, but have most of the fish eggs and all the young fishes. Some of the differences in further detail may be due to the depth at which the shear-net was towed, but the broad lines of difference are clearly seen to be caused by the nature of the nets.

In order to determine more definitely, without any disturbing influence due to depth, the difference in catching power between the large open-meshed shear-net and the much smaller ordinary tow-net made of fine-meshed silk, we tied a tow-net to the frame of the shear-net so that the two would work together side by side, and we show here in Form **105** the results of two such double hauls.

In the first place, it will be noticed that the shear-net

**47.** —One mile W. of Bradda Head, April 23rd, 1907. Shear* = Calf Island to Bradda.

| Net used | Surface | Surface | Shear | Shear* |
|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 10 | 10 |
| Catch in c.cm. | 12·5 | 13 | 75·5 | 78 |
| Biddulphia mobiliensis | — | 500 | — | — |
| Coscinodiscus concinnus | 500 | 500 | — | — |
| Peridinium sp. | 500 | 1,000 | — | — |
| Pleurobrachia pileus | — | — | 4 | — |
| Medusoid gonophores | 10 | 100 | 4,500 | 240 |
| Sagitta bipunctata | — | 2 | 200 | 400 |
| Tomopteris onisciformis | — | — | — | 3 |
| Larval Polychaeta | 50 | 50 | 440 | — |
| 'Mitraria' | 100 | 100 | — | — |
| Crab zoea | 6 | 3 | 280 | 1,600 |
| Mysis stage of Crangon | 5 | 8 | 1,800 | 1,900 |
| Nephrops, 1st stage | 1 | — | 1,600 | 600 |
| Evadne nordmanni | 100 | 50 | — | — |
| Calanus helgolandicus | 1,500 | 1,250 | 4,000 | 13,480 |
| Pseudocalanus elongatus | 300 | 200 | 480 | 240 |
| Temora longicornis | 250 | 300 | 560 | 2,300 |
| Centropages hamatus | 50 | 100 | 40 | — |
| Anomalocera pattersoni | 10 | 100 | 40 | 60 |
| Acartia clausi | 8,000 | 6,200 | 120 | 1,000 |
| Oithona similis | 2,350 | 2,200 | 40 | — |
| Metridia lucens | — | — | 20 | 3 |
| Candacia armata | — | — | 2 | — |
| Copepod nauplii | 8,500 | 11,500 | — | — |
| „ juv. | 2,000 | 2,000 | — | — |
| Barnacle nauplii | — | — | 1,000 | 360 |
| „ cypris stage | 43 | 280 | 10 | — |
| Oikopleura sp. | 700 | 1,000 | 1,000 | — |
| Fish eggs:— | | | | |
| Rockling | 12 | 17 | 36 | 60 |
| Whiting | 4 | 16 | 32 | 15 |
| Cod | 2 | 4 | 18 | 8 |
| Green Cod | 3 | 8 | 10 | 10 |
| Bib | 3 | 9 | 37 | 20 |
| Grey Gurnard | — | — | 8 | 4 |
| Dragonet | 4 | 2 | 10 | 6 |
| Haddock | — | — | 4 | 3 |
| Top-knot | — | — | 8 | — |
| Dab | 3 | 1 | 3 | 2 |
| Sprat | 2 | 4 | 6 | 6 |
| Young fishes:— | | | | |
| Gadoid | — | — | 30 | 70 |
| Larval Gadoid | — | — | — | 7 |
| Sand-eel | — | — | — | 1 |
| Post-larval Agonus | — | — | — | 1 |

## 105.—Mid-Channel, September 12th, 1907.

| Net used | Shear A | Tow-net A | Shear B | Tow-net B |
|---|---|---|---|---|
| Depth in fathoms | 10 | 10 | 20 | 20 |
| Catch in c.cm. | 18·5 | 11 | 13·5 | 2 |
| Biddulphia mobiliensis | — | — | — | 130 |
| Chaetoceros contortum | — | — | — | 1,250 |
| ,, debile | — | — | — | 3,700 |
| ,, decipiens | — | 3,000 | 20 | 3,500 |
| ,, sociale | — | — | — | 750 |
| ,, teres | — | 7,500 | — | 23,000 |
| ,, convolutum | — | — | — | 1,300 |
| ,, densum | — | 2,000 | — | 1,500 |
| ,, diversum | — | — | — | 400 |
| ,, subtile | — | 13,500 | — | 5,000 |
| Coscinodiscus concinnus | — | 500 | — | 600 |
| ,, radiatus | — | 4,500 | — | 4,000 |
| Ditylium brightwellii | — | — | — | 120 |
| Eucampia zodiacus | — | 500 | — | 130 |
| Rhizosolenia semispina | — | 80,000 | 500 | 165,000 |
| ,, shrubsolei | — | 500 | 50 | 625 |
| ,, alata | — | — | — | 3,400 |
| ,, stolterfothii | — | 500 | — | 1,500 |
| ,, setigera | — | 250 | — | — |
| Lauderia borealis | — | 500 | — | 1,000 |
| Leptocylindrus danicus | — | — | — | 600 |
| Asterionella japonica | — | — | — | 120 |
| Ceratium fusus | — | 500 | 50 | 250 |
| ,, tripos | 10 | 5,000 | 50 | 3,000 |
| Peridinium sp. | — | 500 | — | 120 |
| Trochiscia sp. | — | 100 | 20 | — |
| Medusoid gonophores | 45 | 1 | 55 | 3 |
| Sagitta bipunctata | 200 | 5 | 135 | 1 |
| Larval Polychaeta | 25 | 1,500 | — | 250 |
| 'Mitraria' | — | 2,000 | — | 120 |
| Crab zoea | 2 | 1 | — | — |
| Mysis stage of Crangon | 2 | — | — | 1 |
| Microniscus calani | 70 | — | 10 | — |
| Calanus helgolandicus | 2,600 | 110 | 275 | 20 |
| Pseudocalanus elongatus | 300 | 33,600 | 285 | 6,250 |
| Temora longicornis | 10 | — | 2 | 1 |
| Centropages hamatus | 6 | 5 | 3 | 2 |
| Acartia clausi | 350 | 3,640 | 450 | 200 |
| Oithona similis | 60 | 2,840 | 65 | 1,200 |
| Microcalanus pusillus | 10 | 200 | 10 | 2,500 |
| Paracalanus parvus | — | 100 | 20 | 160 |
| Copepod nauplii | 30 | 24,000 | 75 | — |
| ,, juv. | 60 | 12,500 | 275 | — |
| Gasteropods, larval | 10 | 1,000 | — | 500 |
| Lamellibranchs, ,, | — | 1,000 | — | 370 |
| Oikopleura sp. | 25 | 1,000 | 50 | 140 |
| Ascidian eggs | 25 | 1,500 | 25 | 600 |

A and its tow-net at about 10 fathoms caught nearly twice as much material as the same two nets (B) worked at about 20 fathoms.

The further point is that in each case the tow-net retained the Diatoms, the Dinoflagellates, the minute larval forms and the smaller Copepoda which had escaped the shear-net, while the latter caught more of the larger organisms, such as Medusae, *Sagitta*, *Micronisicus*, and the large Copepod *Calanus*. The number of organisms in the tow-net in each case is enormously greater, but those in the shear-net bulk larger on account of their individual size.

Taking the last item on the lists as an example, the obvious explanation of the numbers would be that there were more Ascidian eggs at 10 fathoms than at 20, and therefore tow-net A caught more than tow-net B; no doubt both shear-nets being so much larger caught still more, but the majority of the eggs passed through the wide meshes, and only a very few (25) were retained accidentally in each case, probably through being entangled in the appendages of larger crustacea or through the blocking up of some of the meshes.

### The Surface Nets.

The two ordinary open tow-nets with a mouth diameter of $14\frac{1}{2}$ inches, and made of silk No. 9, with 94 threads to the inch, were towed side by side on the surface of the sea about 50 feet behind the ship for fifteen minutes on each occasion. In the great majority of cases it may be certain that their catch was limited to the upper two feet of the sea; and yet notwithstanding the uniformity of the conditions the results were in many cases very different. The following list shows the bulk of the catches on the various occasions when the two nets were

used together, and although some show identical results, as on April 15th, 19th, 22nd, August 21st, 24th, 27th, September 6th and 20th, and in other cases amounts which are very nearly the same, such as 16 c.c. and 15·5 c.c. on April 13th and April 19th, 9 c.c. and 9·5 c.c. on April 16th, 10·5 and 11 c.c. on September 12th, &c.; still other cases are very different, such as 14 and 1, 8 and 2·5, 17 and 42·5, 1·5 and 7 c.c. respectively.

| | Net B | Net C | | Net B | Net C |
|---|---|---|---|---|---|
| April | 1— 8 c.c. | 25 c.c. | Aug. | 21— 1·5 c.c. | 7 |
| | 2—17 | 42·5 | | 21— 3 | 3 |
| | 4—14 | 1 | | 23— 9 | 6·5 |
| | 5— 9 | 12 | | 23— 4·5 | 4 |
| | 8—20 | 12 | | 23— 5 | 2 |
| | 9— 8 | 2·5 | | 24— 2 | 1·5 |
| | 9— 9 | 11·5 | | 24— 2 | 2 |
| | 10—12 | 18·5 | | 26— 1 | 2 |
| | 10— 7 | 8·5 | | 27— 1 | 1 |
| | 11—16·5 | 10 | | 28— 3 | 4 |
| | 11—11·5 | 15 | | 28— 1·5 | 3 |
| | 13—23·5 | 16 | | 28— 1 | 2 |
| | 13—16 | 15·5 | | 29— 4·5 | 3 |
| | 13—20·5 | 24 | Sept. | 2— 2·2 | 1 |
| | 15—11 | 5 | | 3— 2 | 1·5 |
| | 15—10 | 10 | | 3— 2·5 | 1·5 |
| | 16—12·5 | 6·5 | | 4— 2 | 2·5 |
| | 16— 9 | 9·5 | | 4— 2 | 3·2 |
| | 18— 8 | 13·5 | | 6— 1·5 | 0·6 |
| | 18—23·5 | 17·5 | | 6— 0·3 | 0·5 |
| | 19—18 | 18 | | 6— 0·7 | 0·2 |
| | 19—15·5 | 16 | | 6— 1·5 | 1·5 |
| | 22—11 | 9·5 | | 6— 1 | 0·7 |
| | 22— 9·5 | 9·5 | | 9— 8·5 | 4 |
| | 23—12·5 | 13 | | 10— 1·2 | 1·5 |
| | 23— 9 | 11 | | 11— 2 | 1·7 |
| | 23— 8·5 | 6·5 | | 11— 1·7 | 2 |
| | 24—20·5 | 15·5 | | 11— 5 | 3·3 |
| | 24— 7 | 15 | | 12—10·5 | 11 |
| | 25— 5·5 | 4·5 | | 13— 3·2 | 4 |
| | 25— 2·5 | 3·5 | | 16— 7·5 | 2·5 |
| | 25— 8 | 7·5 | | 17— 1·5 | 3 |
| | 26— 6·5 | 9 | | 18—12·5 | 13·5 |
| | 26— 4 | 4·5 | | 18— 2·5 | 4·5 |
| | 27— 6 | 8 | | 19— 2 | 2·5 |
| | 27— 3·5 | 11·5 | | 20— 4 | 6 |
| | 27— 7 | 13 | | 20— 5 | 5 |
| | | | | 20— 2·5 | 5 |
| | | | | 20— 2·5 | 3 |

Even when the results are very much alike quantitatively they may be very different qualitatively.

## 45.—Along N. shore of Calf Island, April 22nd, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight | Shear |
|---|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 10-5 | 10-5 | 5 | 5 |
| Catch in c.cm. | 9·5 | 9·5 | 1·5 | 1 | 19·5 | 52 |
| Biddulphia mobiliensis | 100 | 100 | 50 | — | — | — |
| Chaetoceros contortum | — | — | 50 | 50 | — | — |
| Coscinodiscus concinnus | 100 | 100 | 50 | 85 | 750 | — |
| Lauderia borealis | — | — | 20 | — | — | — |
| Ceratium furca | — | — | 50 | 25 | — | — |
| ,, fusus | 100 | 100 | 30 | — | 500 | — |
| ,, tripos | 100 | 100 | — | 50 | 500 | — |
| Peridinium sp. | 200 | 200 | 60 | 100 | 500 | — |
| Pleurobrachia pileus | — | — | — | — | — | 6 |
| Medusoid gonophores | 50 | 150 | 8 | 4 | 550 | 2,600 |
| Sagitta bipunctata | — | — | — | 1 | 50 | 200 |
| Autolytus prolifer | — | — | — | — | 2 | — |
| Tomopteris onisciformis | — | — | — | — | 1 | 2 |
| Larval Polychaeta | 150 | 150 | 5 | 4 | 150 | 900 |
| 'Mitraria' | 50 | 50 | — | — | 100 | — |
| Crab zoea | 4 | 2 | — | — | 45 | 120 |
| Mysis stage of Crangon | 3 | 2 | — | 7 | 40 | 800 |
| Nephrops, 1st stage | — | — | — | — | 8 | 100 |
| ,, 2nd stage | — | — | — | — | — | 1 |
| Podon intermedium | 50 | 50 | — | — | 100 | — |
| Evadne nordmanni | 50 | 100 | 5 | — | 200 | — |
| Calanus helgolandicus | 600 | 600 | 15 | 20 | 1,000 | 4,600 |
| Pseudocalanus elongatus | 400 | 350 | 50 | 20 | 2,000 | 300 |
| Temora longicornis | 500 | 550 | 45 | 50 | 2,100 | 950 |
| Centropages hamatus | 100 | 50 | 2 | — | — | 40 |
| Anomalocera pattersoni | — | — | 3 | — | — | 80 |
| Acartia clausi | 2,200 | 1,450 | 55 | 75 | 1,400 | 160 |
| Oithona similis | 1,100 | 1,550 | 15 | 15 | 2,000 | — |
| Anomalocera juv. | 50 | 50 | — | — | 50 | — |
| Metridia lucens | — | — | — | — | — | 25 |
| Copepod nauplii | 5,000 | 5,000 | 2,500 | 3,000 | 6,000 | — |
| ,, juv. | 4,000 | 3,250 | 100 | 100 | 6,000 | — |
| Barnacle nauplii | 150 | 100 | 5 | 6 | 300 | 600 |
| ,, cypris stage | 24 | 16 | 3 | 3 | 100 | 3 |
| Oikopleura sp. | 750 | 750 | 35 | 25 | 1,750 | 280 |
| Fish eggs: Rockling | 19 | 23 | — | 2 | 25 | 100 |
| Whiting | 3 | 1 | — | — | 3 | 36 |
| Grey Gurnard | — | — | — | — | — | 10 |
| Red Gurnard | — | — | — | — | — | 6 |
| Cod | — | — | — | — | — | 33 |
| Green Cod | 2 | 2 | — | — | — | 31 |
| Haddock | — | 1 | — | — | — | 10 |
| Com. Dragonet | 4 | 1 | — | — | 3 | 15 |
| Spotted Dragonet | 1 | — | — | — | — | 2 |
| Bib | 1 | 1 | — | — | 2 | 30 |
| Brill | — | — | — | — | — | 2 |
| Topknot | — | — | — | — | — | 4 |
| Dab | 1 | 2 | — | — | — | 3 |
| Young fishes: Sand-eels | — | — | — | — | 5 | 10 |
| Gadoid | — | — | — | — | 10 | 40 |
| Pleuronectid | — | — | — | — | — | 1 |
| Butterfish | — | — | — | — | — | 3 |

and it is by no means always the two hauls that are most alike in bulk that agree best in the kind and number of organisms.

On reflection, it will probably be agreed that it is unlikely that, with the large, varied and irregularly scattered population that we find the sea to contain, two nets should often catch the same quantities of the same sets of organisms. Consequently a result like that obtained on April 22nd (Form **45**), where the two nets caught precisely the same amounts, and where the lists of organisms constituting the hauls are almost exactly alike both in kinds and numbers, is interesting. It will be noticed how different the catch of the weighted net (exactly similar to B and C but ranging through a lower level of water) was on this occasion. The shear-net being of much larger size and having a much coarser mesh naturally gave very different results. It is not comparable with any of the other nets.

As an example of a case where two similar nets, hauled side by side on the same occasion, gave very nearly the same amount of material, but where the kinds and numbers of organisms present in the catch when examined were found to be very different, I give the following lists of the contents* of the two surface nets after a 15-minutes haul on April 13th, 1907, at Station III. The one net contained 16 c.c. and the other 15·5 c.c., but these amounts were made up very differently in the two cases. For example, it will be seen that in the net C there were no Balanus nauplii and no immature Copepoda, while thousands of both were present in B. Then, again, in B there were very few adult *Temora*, while in C practically all the *Temora* were adult. The lists will show other

* Only omitting those organisms of which fewer than ten individuals were obtained.

points of difference. We may add that in the haul of the shear-net, taken at the same place and time, there were 1,380 larvae of *Pectinaria* in tubes along with 5,400 Balanus nauplii, and many other organisms.

| | Net B = 16 c.cm. | | Net C = 15·5 c.cm. |
|---|---|---|---|
| Larval Polychaeta | 650 | ... | 0 |
| Balanus nauplii | 3,000 | ... | 0 |
| ,, cypris stage | 50 | ... | 0 |
| Copepoda nauplii | 7,000 | ... | 2,000 |
| ,, juv. | 13,000 | ... | 0 |
| Calanus helgolandicus | 100 | ... | 6 |
| Pseudocalanus elongatus | 850 | ... | 500 |
| Temora longicornis | 2,470 | ... | 4,750 |
| Oithona similis | 100 | ... | 50 |
| Acartia clausi | 250 | ... | 200 |
| Centropages hamatus | 0 | ... | 200 |
| Coscinodiscus concinnus | 8,000 | ... | 14,000 |
| Biddulphia mobiliensis | 40,000 | ... | 70,000 |
| Rhizosolenia semispina | 1,000 | ... | 3,000 |
| Lauderia borealis | 1,000 | ... | 0 |
| Thalassiosira nordenskioldii | 2,000 | ... | 7,000 |
| ,, subtilis | 6,000 | ... | 0 |
| Chaetoceros teres | 0 | ... | 1,000 |
| Peridinium sp. | 500 | ... | 0 |
| Plutei | 500 | ... | 1,000 |
| Oikopleura sp. | 2,000 | ... | 150 |
| Medusoids | 50 | ... | 25 |
| Sagitta bipunctata | 0 | ... | 48 |
| Crab zoeas | 0 | ... | 10 |

This shows very clearly that the two gatherings, although alike in quantity, were unlike in quality.

Another example (Form **41**) is given here from April 19th, where the catch in each case was 18 c.c., but the amount is made up in very different ways. Out of a total of 38 organisms in the two surface nets there are nine which are absent from one or the other net. Of those present in both the numbers differ notably in a few cases, such as 1,000 : 4,000 ; 1,000 : 3,000 ; and 500 : 3,000 : in other cases again, such as "Mitraria" and Copepod nauplii, the numbers agree exactly. It will be noticed that the Nansen net caught more than the Hensen—both fishing through the lower half of the water (20 to 10 fathoms)—and that the weighted net, ranging through the upper

## 41.—Off-shore Station I, April 19th, 1907.

| Net used | I | II | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 |
| Catch in c.cm. | 18 | 18 | 2 | 8 | 29 |
| Biddulphia mobiliensis | 1,000 | 4,000 | 170 | 700 | 3,000 |
| Chaetoceros contortum | — | 1,000 | 17,000 | 36,000 | — |
| ,, decipiens | — | — | 500 | 2,000 | — |
| ,, sociale | — | — | 1,500 | 1,000 | — |
| Coscinodiscus concinnus | 1,000 | 3,000 | 170 | 700 | 500 |
| Ditylium brightwellii | — | — | 100 | 500 | — |
| Eucampia zodiacus | — | — | — | 500 | — |
| Rhizosolenia semispina | — | 250 | 100 | 3,000 | — |
| ,, shrubsolei | — | — | — | 2,000 | — |
| Thalassiosira nordenskioldii | — | 11,000 | 40,000 | 140,000 | 3,000 |
| Lauderia borealis | — | 100 | 8,000 | 8,000 | — |
| Leptocylindrus danicus | — | — | 1,000 | 4,000 | — |
| Ceratium furca | — | — | — | 700 | — |
| ,, fusus | — | — | 500 | 500 | — |
| ,, tripos | — | — | 500 | — | 1,000 |
| Peridinium sp. | 500 | 3,000 | 1,500 | 1,000 | 2,500 |
| Medusoid gonophores | 150 | 115 | 10 | 125 | 100 |
| Sagitta bipunctata | 1 | 3 | 5 | 32 | 40 |
| Larval Polychaeta | 110 | 75 | 4 | 8 | 20 |
| 'Mitraria' | 350 | 350 | — | — | 200 |
| Crab zoea | 1 | — | 1 | 2 | 10 |
| Mysis stage of Crangon | — | — | 3 | 40 | 104 |
| Nephrops, 1st stage | — | — | 2 | 10 | 34 |
| Podon intermedium | — | 75 | 5 | — | — |
| Evadne nordmanni | 50 | 330 | 10 | — | 50 |
| Calanus helgolandicus | 600 | 900 | 5 | 125 | 1,000 |
| Pseudocalanus elongatus | 700 | 300 | 85 | 1,300 | 3,800 |
| Temora longicornis | 700 | 225 | 40 | 550 | 3,000 |
| Centropages hamatus | 400 | 230 | 5 | 50 | 25 |
| Acartia clausi | 3,000 | 2,000 | 45 | 220 | 1,250 |
| Oithona similis | 1,700 | 2,000 | 10 | 25 | 1,000 |
| Anomalocera juv. | 100 | 40 | 5 | — | 50 |
| Copepod nauplii | 3,000 | 3,000 | 10,000 | 15,000 | 5,000 |
| ,, metanauplii | 200 | 190 | — | — | 50 |
| ,, juv. | 3,000 | 9,000 | 75 | 4,500 | 8,000 |
| Barnacle nauplii | 120 | 80 | 10 | 25 | 50 |
| ,, cypris stage | 12 | 25 | 1 | 1 | — |
| Oikopleura sp. | 900 | 650 | 55 | 300 | 650 |
| Fish eggs: Rockling | 5 | 2 | — | 1 | — |
| Whiting | 9 | 7 | — | — | 4 |
| Cod | 3 | 8 | — | 3 | 4 |
| Green Cod | 4 | 3 | — | 1 | 7 |
| Bib | 9 | 5 | — | — | 9 |
| Common Dragonet | 1 | 3 | — | — | 1 |
| Haddock | 1 | — | — | — | — |
| Grey Gurnard | — | 2 | — | — | — |
| Topknot | — | 3 | — | — | — |
| Dab | 4 | 1 | — | — | 2 |
| Sprat | 2 | 1 | — | 2 | — |
| Young fishes: Gadoid | — | — | — | 1 | 3 |
| Sand-eel | — | — | — | — | 1 |

half of the water, caught as usual more than either the deep or the surface nets. We have much evidence of this kind that the most populous zone in the sea is below the surface but above ten fathoms.

We print also Form **42** for comparison with Form **45**. The hauls were taken only three days apart but at different localities, Form **45** representing the along-shore station IV, while Form **42** records a haul from off-shore station II, nearly ten miles off. In **42**, although the amounts in the two surface nets are nearly the same, 15·5 and 16 c.c., still the quantities of the various organisms present differ considerably in the two cases. Of some few (e.g. *Podon* and *Evadne*) the numbers are alike, but with other organisms (*Biddulphia* and *Coscinodiscus*) twice as many are in the one net as in the other; some Copepoda show like numbers, others are in the proportion of nearly ten to one. The Nansen net here, as usual, catches more than the Hensen, and the weighted net with its deeper range more than the otherwise similar surface nets. It will be noticed that the shear-net got relatively large numbers of the larger organisms, *Pleurobrachia*, Medusae, *Sagitta*, and the larger larvae.

Form **42** is of interest also when compared with **41**, representing off-shore station I, at practically the same time (within an hour). They are clearly similar hauls having the same general *facies* although all the numbers differ in detail.

The marked difference of **45** (the later date, April 22nd) to both **41** and **42** (April 19th) in the proportion of Diatoms to Copepoda present is noteworthy. A glance at the lists shows the disproportion, and the total numbers are:—

| | | | | | |
|---|---|---|---|---|---|
| Form | 41: | Diatoms, | 300,000; | Copepoda, | 22,985 |
| ,, | 42: | ,, | 458,000; | ,, | 20,218 |
| ,, | 45: | ,, | 1,450; | ,, | 24,620 |

## 42.—Off-shore Station II, April 19th, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight | Shear |
|---|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 | 7 |
| Catch in c.cm. | 15·5 | 16 | 3·5 | 7·5 | 23·5 | 28 |
| Biddulphia mobiliensis | 1,500 | 3,000 | — | 700 | 2,000 | — |
| Chaetoceros contortum | — | — | 27,000 | 57,000 | 2,000 | |
| ,, decipiens | — | — | 1,000 | 2,000 | — | — |
| ,, sociale | — | — | 2,000 | 4,000 | — | — |
| Coscinodiscus concinnus | 1,500 | 3,500 | 300 | 700 | 3,500 | — |
| Ditylium brightwellii | — | — | 500 | 1,000 | — | — |
| Eucampia zodiacus | — | — | 500 | 1,000 | — | — |
| Rhizosolenia semispina | 500 | — | 800 | 3,000 | 500 | — |
| ,, shrubsolei | — | — | 1,500 | — | — | — |
| Thalassiosira gravida | — | — | 4,500 | 1,000 | — | — |
| ,, nordenskioldii | 4,000 | 5,500 | 80,000 | 170,000 | 45,000 | — |
| Leptocylindrus danicus | — | — | 4,000 | 3,000 | 500 | — |
| Lauderia borealis | — | — | 10,000 | 10,000 | — | — |
| Rhizosolenia stolterfothii | — | — | — | 1,000 | — | — |
| Ceratium furca | — | 1,000 | 2,500 | 1,000 | 500 | — |
| ,, fusus | — | 500 | — | — | 500 | — |
| ,, tripos | 250 | 1,500 | 500 | 1,000 | — | — |
| Peridinium sp. | 250 | 3,000 | 3,500 | 6,000 | 2,000 | — |
| Pleurobrachia pileus | — | — | — | — | 1 | 11 |
| Medusoid gonophores | 150 | 110 | 18 | 60 | 350 | 1,100 |
| Sagitta bipunctata | 2 | 1 | — | 3 | 23 | 310 |
| Larval Polychaeta | 5 | 5 | — | 5 | 10 | 230 |
| Crab zoea | — | — | — | 1 | 6 | 7 |
| Mysis stage of Crangon | 1 | — | 5 | 12 | 30 | 145 |
| Nephrops 1st stage | — | — | — | 2 | 4 | 15 |
| Podon intermedium | 40 | 40 | 8 | 5 | 20 | — |
| Evadne nordmanni | 75 | 75 | 10 | 15 | 250 | — |
| Calanus helgolandicus | 750 | 970 | 30 | 75 | 450 | 300 |
| Pseudocalanus elongatus | 1,000 | 187 | 30 | 400 | 2,000 | 187 |
| Temora longicornis | 1,100 | 150 | 50 | 150 | 1,000 | 670 |
| Centropages hamatus | 190 | 112 | 10 | 5 | 50 | 20 |
| Anomalocera pattersoni | 80 | 37 | 10 | — | 50 | 10 |
| Acartia clausi | 3,000 | 3,000 | 75 | 150 | 1,700 | 75 |
| Oithona similis | 500 | 500 | 25 | 30 | 1,350 | — |
| Anomalocera juv. | 260 | 75 | 25 | — | — | — |
| Copepod nauplii | 4,500 | 8,000 | 4,000 | 7,000 | 10,000 | — |
| ,, juv. | 5,600 | 6,000 | 550 | 1,250 | 9,500 | — |
| Barnacle nauplii | 40 | 40 | 15 | 45 | 100 | 850 |
| ,, cypris stage | 16 | 8 | 2 | 3 | 6 | — |
| Oikopleura sp. | 800 | 1,200 | 75 | 160 | 1,000 | 1,250 |
| Fish eggs: Rockling | 2 | — | — | — | — | 4 |
| Whiting | 12 | 6 | — | — | 3 | 6 |
| Cod | 4 | 2 | — | 1 | — | — |
| Grey Gurnard | 3 | 4 | — | — | 1 | 2 |
| Com. Dragonet | 3 | 1 | — | — | 1 | 2 |
| Bib | 14 | 3 | — | 1 | 9 | 2 |
| Haddock | 3 | 1 | — | — | 1 | — |
| Topknot | — | 1 | — | — | 1 | 2 |
| Dab | 6 | 1 | — | 1 | — | — |
| Sprat | 2 | 2 | — | — | — | 3 |
| Green Cod | 11 | 1 | — | — | — | 1 |
| Young fishes: Plaice | — | — | — | 1 | — | — |
| Gadoid | — | — | — | — | 6 | 6 |

The Copepoda are remaining fairly constant, while the Diatoms, having passed their spring maximum, are falling off rapidly.

On Forms **16**, **19**, we give the results of hauls taken on the along-shore station III, off the Slock, on two adjoining days, April 9th and 10th. The two surface hauls are very unlike in quantity, although practically the same series of organisms is represented. Such numbers as 37,000 to 1,500; 4,000 to 250; and 19,000 to 550 indicate a considerable disproportion. The surface plankton, then, if we may judge from these two samples, had fallen on April 10th to less than half what it had been on the previous day. But if we compare the two hauls taken on April 10th, we find that the second net towed simultaneously with the first, but at about a fathom below the surface, yielded a much more abundant gathering. On looking into the details one finds that all the Diatoms and *Ceratium tripos* are more numerous in the deeper haul, while the larger organisms—Medusae, Larvae, Copepoda, and Oikopleura—are more abundant on the surface. Some of the Diatoms showed a great increase below the surface, the extreme case being *Chaetoceros contortum* with 120,000 at one fathom to 1,500 at the surface.

On the other hand during the later summer we met with cases where the Copepoda and other larger organisms were much more abundant in a zone below the surface. Here is an example (Form **84**) from off-shore station II, on August 27, where the weighted net brought up 7·5 c.c. as against 1 c.c. in each of the surface nets – all three nets being alike and used simultaneously. The relatively large numbers of *Acartia*, *Pseudocalanus*, and Copepod Nauplii will be noticed. The two surface nets on this occasion yielded identical quantities, but the detailed

## 16, 19.—Three miles off Slock.

| | (16) April 9th | (19) April 10th | |
|---|---|---|---|
| Depth in fathoms | 0 | 0 | 1 |
| Catch in c.cm. | 33 | 13 | 20 |
| Biddulphia mobiliensis | 11,000 | 8,000 | 12,000 |
| Chaetoceros contortum | 37,000 | 1,500 | 120,000 |
| ,, decipiens | 4,000 | 250 | 8,000 |
| ,, teres | — | — | 500 |
| Coscinodiscus concinnus | 7,000 | 3,500 | 5,000 |
| Rhizosolenia semispina | — | 150 | 300 |
| Thalassiosira nordenskioldii | 21,000 | 1,500 | 78,000 |
| ,, subtilis | — | 500 | 3,000 |
| Lauderia borealis | — | — | 5,000 |
| Ceratium fusus | — | — | 200 |
| ,, tripos | 1,000 | 100 | 1,000 |
| Peridinium sp. | 1,000 | 100 | — |
| Medusoid gonophores | — | 75 | 90 |
| Sagitta bipunctata | 11 | — | — |
| 'Mitraria' | — | 250 | 100 |
| Crab zoea | 30 | — | — |
| Mysis stage of Crangon | 2 | — | — |
| Larval Nephrops, 1st stage | 4 | — | — |
| Podon intermedium | — | 20 | — |
| Evadne nordmanni | 500 | — | — |
| Calanus helgolandicus | 50 | 100 | 60 |
| Pseudocalanus elongatus | 16,000 | 2,200 | 1,000 |
| Temora longicornis | 19,000 | 550 | 220 |
| Centropages hamatus | 600 | 30 | 15 |
| Acartia clausi | 1,000 | 185 | 75 |
| Oithona similis | — | 90 | 75 |
| Anomalocera juv. | 200 | 20 | 15 |
| Copepod nauplii | 8,000 | 5,000 | 4,000 |
| ,, juv. | 6,000 | 2,250 | 900 |
| Barnacle nauplii | — | 825 | 550 |
| ,, cypris stage | 6 | 10 | 8 |
| Oikopleura sp. | 100 | 2,000 | 1,000 |
| Fish eggs— | | | |
| Rockling | 2 | 2 | 3 |
| Grey Gurnard | 12 | — | — |
| Common Dragonet | 13 | 3 | 3 |
| Spotted Dragonet | — | 1 | — |
| Bib | 26 | 2 | 2 |
| Red Gurnard | — | 1 | — |
| Whiting | 132 | 4 | 3 |
| Sail Fluke | — | 1 | — |
| Dab | 14 | 2 | — |
| Long Rough Dab | 1 | — | — |
| Cod | 55 | 1 | — |
| Green Cod | 26 | — | — |
| Topknot | — | — | 1 |
| Haddock | 22 | — | — |
| Plaice | 1 | — | — |
| Sprat | 23 | — | — |

figures for the species are in nearly every case different, although, as we have pointed out in other examples, they are of the same "order."

**84.**—Train Bank, August 27th.

| Depth in fathoms ..... | 0 | 0 | Weight |
|---|---|---|---|
| Catch in c.cm. ..... | 1 | 1 | 7½ |
| Chaetoceros teres ..... | 30 | 50 | — |
| Coscinodiscus concinnus ..... | 40 | 75 | — |
| Coscinodiscus radiatus ..... | — | — | 200 |
| Ceratium fusus ..... | 50 | 250 | — |
| ,, tripos..... | 150 | 600 | 400 |
| Trochiscia sp..... | 40 | 100 | 100 |
| Sagitta bipunctata ..... | 3 | 1 | 27 |
| Crab zoea ..... | — | — | 4 |
| Mysis stage of Crangon ..... | — | — | 2 |
| Calanus helgolandicus..... | 5 | 4 | 200 |
| Pseudocalanus elongatus ..... | 80 | 70 | 3,000 |
| Temora longicornis ..... | 10 | 20 | 500 |
| Centropages hamatus ..... | 30 | 10 | 100 |
| Anomalocera pattersoni ..... | 4 | — | — |
| Acartia clausi ..... | 550 | 500 | 24,700 |
| Oithona similis ..... | 15 | — | — |
| Isias clavipes ..... | 30 | 30 | — |
| Parapontella brevicornis..... | — | 3 | — |
| Paracalanus parvus ..... | 20 | 15 | — |
| Copepod nauplii..... | 9,000 | 7,000 | 26,500 |
| ,, juv. ..... | 2,000 | 1,500 | 7,000 |
| Gasteropods, larval ..... | 50 | 150 | 200 |
| Fish eggs—Rockling..... | — | 1 | 1 |
| Ascidian eggs ..... | 2,500 | 1,000 | 2,400 |

### Comparison of Deep and Surface Hauls.

We have shown in the previous section that in some cases (April) the surface gatherings contain more Copepoda and larval forms, and in others (August) these larger organisms are more abundant in deeper zones (see Forms **19** and **84**). When a comparison is made between the three similar open tow-nets which were worked together for 15 minutes at a time—two, at or close to, the surface (0 fathoms) and the other weighted so that it was lowered to a depth of about ten fathoms, and gradually rose, as the boat went slowly ahead, to a depth of a

fathom or two below the surface—it is almost invariably found that the weighted net, with its wider range through the deeper layers of waters, gave a larger, and sometimes a much larger, quantity of organisms. The only exceptions to this rule are on some occasions, in April, when the sea was full of Diatoms and the surface nets gave very large hauls, equal to or even exceeding the deeper ones. But even during the Diatom maximum in April some days showed more in the weighted than in the surface nets. For example, on April 10th, at along-shore station III (Form **22**), the surface gave 11·5 and the net at one fathom 19·5 c.c., and the total Diatoms were 27,000 in the former and 188,000 in the latter (see also Form **19**, same date, above).

Such numbers as 18, 18, 29; 3, 3, 6·5; 15·5, 16, 23·5; 9·5, 9·5, 19·5; and 9, 11, 18 are frequent. On April 25th, the numbers are 5·5, 4·5 at the surface and 20 in the deeper net. In some cases the difference is even more marked, as, for example, on August 24th, at off-shore station II, when the surface nets gave respectively 2 and 1·5 c.c., while the weighted net gave 16 c.c. The increase in this case was due to Copepoda being more abundant in the lower zone, especially *Acartia clausi* (23,000), *Oithona similis* (1,500), and Copepod nauplii (70,000). Other similar results were obtained at the same locality on neighbouring days.

Here is a haul (Form **38**) ten miles off shore, in April, where the two surface nets gave very different results and the weighted net did not exceed them in quantity. The bulk of the catch in all three nets was Copepoda both young and old. *Oikopleura* is rather evenly distributed in these nets, there being roughly 3,000 in each. The shear-net haul was taken on the way in, half-way between the Calf Island and Port Erin, and shows an extraordinary

## 38.—Off-shore Station II, April 18th, 1907.

| Net used | Surface | Surface | Hensen | Nansen | Weight | Shear |
|---|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 20-10 | 20-10 | 10-0 | 7 |
| Catch in c.cm. | 23·5 | 17·5 | 5·5 | 9·5 | 17·5 | 27·5 |
| Biddulphia mobiliensis | 750 | 2,250 | 500 | 250 | 2,500 | 1,000 |
| Chaetoceros contortum | — | 250 | 36,000 | 63,000 | 500 | 250 |
| ,, debile | — | — | — | 2,000 | — | — |
| ,, decipiens | — | — | 2,500 | 4,000 | — | — |
| ,, sociale | — | — | 1,500 | 2,000 | — | — |
| Coscinodiscus concinnus | 1,750 | 2,750 | 200 | 250 | 1,100 | 200 |
| Ditylium brightwellii | — | — | 500 | — | — | — |
| Eucampia zodiacus | — | — | 1,000 | — | — | — |
| Lauderia borealis | — | — | 5,000 | 14,000 | 500 | — |
| Rhizosolenia shrubsolei | 250 | 250 | 2,000 | 2,000 | 500 | — |
| ,, stolterfothii | — | — | 1,000 | 2,000 | — | — |
| Thalassiosira gravida | — | — | 500 | 1,000 | — | — |
| ,, nordenskioldii | 2,000 | 4,500 | 65,000 | 134,000 | 8,500 | 500 |
| Leptocylindrus danicus | — | — | 4,000 | 3,000 | 250 | — |
| Ceratium furca | — | — | 1,000 | 500 | — | — |
| ,, fusus | 250 | 250 | — | 500 | 1,500 | — |
| ,, tripos | 500 | 750 | — | — | 1,000 | — |
| Peridinium sp. | — | 2,250 | 500 | 6,000 | 750 | — |
| Acanthometra sp. | — | — | — | 100 | 50 | — |
| Medusoid gonophores | 200 | 250 | 10 | 120 | 300 | 1,800 |
| Plutei of Echinoderms | 200 | 200 | — | — | — | — |
| Sagitta bipunctata | 12 | — | 1 | 6 | 27 | 123 |
| Autolytus prolifer | — | — | — | — | — | 1 |
| Larval Polychaeta | 60 | 50 | — | 20 | 20 | 250 |
| 'Mitraria' | 400 | 250 | — | — | 500 | — |
| Crab zoea | 20 | — | — | — | 8 | 16 |
| Mysis stage of Crangon | 2 | — | 2 | 10 | 37 | 72 |
| Nephrops first stage | — | — | — | 4 | 4 | 11 |
| Podon intermedium | 150 | 150 | — | — | — | — |
| Evadne nordmanni | 100 | 100 | — | — | 150 | 50 |
| Calanus helgolandicus | 1,600 | 600 | 10 | 120 | 1,200 | 850 |
| Pseudocalanus elongatus | 200 | 150 | 100 | 770 | 1,600 | 500 |
| Temora longicornis | 300 | 200 | 30 | 150 | 2,300 | 750 |
| Centropages hamatus | 100 | 100 | — | — | — | 50 |
| Anomalocera pattersoni | 500 | 400 | 5 | — | — | — |
| Acartia clausi | 2,600 | 2,400 | 40 | 125 | 1,600 | 50 |
| Oithona similis | 400 | 300 | 5 | 50 | 150 | — |
| Copepod nauplii | 250 | 4,500 | 4,000 | — | 7,000 | 250 |
| ,, juv. | 2,000 | 3,000 | 100 | 18,000 | 4,000 | 150 |
| Barnacle nauplii | 30 | 25 | 10 | 75 | 75 | 650 |
| ,, cypris stage | 2 | — | 1 | — | — | 6 |
| Oikopleura sp. | 3,300 | 2,750 | 140 | 500 | 3,300 | 750 |
| Fish eggs:—Rockling | 6 | 1 | — | — | — | 9 |
| Common Dragonet | 10 | 2 | — | — | 4 | 7 |
| Topknot | 1 | 3 | — | — | — | — |
| Bib | 9 | 8 | 1 | 1 | 2 | 5 |
| Whiting | 13 | 12 | — | — | 11 | 3 |
| Cod | 8 | 1 | — | — | — | 1 |
| Green Cod | 1 | 3 | — | 2 | 2 | 4 |
| Haddock | 1 | 4 | — | — | — | — |
| Gurnard | — | 1 | — | — | 2 | — |
| Dab | — | 5 | — | — | — | — |
| Sprat | — | 1 | — | — | — | 2 |
| Spotted Dragonet | — | — | — | — | — | 1 |
| *Young fishes*: Gadoid | — | — | 1 | 1 | 2 | 10 |
| *Clupeoids* | — | — | — | — | — | 10 |

number of Medusoids. most of which were *Hybocodon prolifer.*

Form **87** shows a set of hauls at the end of August on Station V inside the Wart Bank. One remarkable

**87.**– Station V, August 29th.

| Net used | Surface | Surface | Hensen | Nansen | Weight |
|---|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 14-7 | 14-7 | 10-0 |
| Catch in c.cm. | 4·5 | 3 | ·3 | ·7 | 30 |
| Biddulphia mobiliensis | 700 | 750 | 20 | 50 | 1,000 |
| Chaetoceros contortum | — | — | 15 | 10 | — |
| „ decipiens | — | — | 15 | — | — |
| Coscinodiscus radiatus | — | — | 10 | — | — |
| „ concinnus | — | 200 | — | — | — |
| Rhizosolenia semispina | 250 | 1,000 | 25 | 10 | — |
| Ceratium fusus | — | 500 | 10 | 10 | 500 |
| „ tripos | 250 | 2,750 | 70 | 20 | 1,000 |
| Peridinium sp. | 250 | 300 | 5 | — | — |
| Trochiscia brachiolata | — | 200 | 10 | 25 | 250 |
| Sagitta bipunctata | 27 | 21 | — | 1 | 125 |
| Tomopteris onisciformis | — | 1 | — | — | — |
| Larval Polychaeta | 200 | — | 40 | — | — |
| 'Mitraria' | 75 | — | — | — | — |
| Crab zoea | — | — | — | — | 2 |
| „ megalopa | 1 | — | — | — | — |
| Mysis stage of Crangon | 5 | 3 | — | 3 | 36 |
| Podon intermedium | 10 | — | — | — | 15 |
| Calanus helgolandicus | 34 | 7 | — | — | 67 |
| Pseudocalanus elongatus | 4,500 | 830 | 100 | 325 | 23,000 |
| Temora longicornis | 200 | 25 | 8 | 10 | 700 |
| Centropages hamatus | 150 | 25 | 5 | 10 | 200 |
| Acartia clausi | 1,255 | 150 | 8 | 100 | 6,000 |
| Oithona similis | 4,500 | 3,250 | 35 | 15 | 6,500 |
| Paracalanus parvus | 200 | 150 | 4 | 6 | — |
| Isias clavipes | — | 25 | — | — | 300 |
| Leptopsyllus sp. | — | — | 150 | — | — |
| Ameira intermedia | — | — | 4 | — | — |
| Zaus goodsiri | — | — | — | — | 2 |
| Copepod nauplii | 17,000 | 22,500 | 340 | 2,450 | 38,000 |
| „ juv. | 15,000 | 750 | 40 | 600 | 19,000 |
| Gasteropods, larval | 250 | 200 | 20 | 50 | 500 |
| Lamellibranchs, larval | 250 | 500 | 20 | 50 | 500 |
| Oikopleura sp. | 875 | 900 | 25 | 10 | — |
| Ascidian eggs | 1,500 | 1,500 | — | — | 2,000 |
| Young fishes | — | — | — | — | 6 |

feature of this occasion was that the Hensen net, hauled up from 14 fathoms, contained 150 specimens of what is probably a new species of *Leptopsyllus*, while the Nansen

net used at the same time, and at the same depth, on the other side of the ship, caught twice as much material but not a single specimen of the new Copepod. The surface nets are also somewhat divergent in their results, while the deeper weighted net has caught a very much larger quantity of material, the greater part of which is clearly made up of Copepoda both young and old—about ninety-five thousand in all.

### Results of the Vertical Hauls.

The two vertical closing nets we have used from the "Ladybird" are the Petersen-Hensen and the Nansen, both of which have now been thoroughly tested, and have given on the whole good results. The ring of the Petersen-Hensen net is 19 inches in diameter, and the opening at the mouth into which the brass lids fit is $7\frac{1}{5}$ inches. The opening of the Nansen net (figs. 3 and 4) is 14 inches.

As a vertical closing net we prefer the Nansen to the Petersen-Hensen. It is lighter and less complicated (a matter of some importance in a rough sea), more easily manipulated, less liable to failure in action, costs less and generally catches more. The brass cylinder at the lower end is, however, too small, and might be improved in other ways.

These two vertical closing tow-nets are obviously not comparable one with the other. Their dimensions are different, and the results of the hauls are usually also very different, the Nansen net almost invariably catching more than the Hensen. The maximum amount for the Hensen is 64·5, while the maximum for the Nansen is more than twice as much, namely, 164 c.c. These two nets were not used for the purpose of obtaining results that would be comparable, but were used for the purpose of testing the

nets to see which was the more efficient and convenient, and also for the purpose of obtaining corroborative evidence as to the distribution of organisms by means of a second and different net used at the same time. Consequently, the results obtained from the two nets cannot be summed, but must be treated separately. The usual plan of working at the off-shore stations was that, after

Fig. 3.—Nansen net going down open.

Fig. 4.—Nansen net coming up closed.

ascertaining the depth, these vertical nets were lowered simultaneously to within a fathom or so of the bottom and were hauled up through the lower ten fathoms of water and then closed by means of the messengers. Thus, the Hensen and Nansen nets brought us up samples of the fauna in the bottom ten fathoms, for comparison with the

fauna of the upper zones of the sea obtained by means of the surface and weighted open tow-nets.

In many of these hauls during April (see Form **10**, p. 119) the vertical nets, although they had traversed a very much smaller area of water, brought up a very much larger number of Diatoms, for example in the case of *Chaetoceros contortum*- 14,000,000 in the Nansen and 286,000 in the Hensen, as against 160,000 in the weight net and smaller numbers in those at the surface. Other cases may not be so striking as this one, but still it is true of many hauls that the Nansen net, especially, brought a large number of Diatoms from the lower zone of water.

In cases where, as on Form **71**, p. 109, the Hensen and Nansen nets have yielded smaller numbers, say, of Copepoda than the weighted and surface nets no conclusions can be drawn, as it must always be remembered that the open tow-nets have sampled very much larger volumes of water than have passed through the vertical nets. Form **21**, p. 117, shows a case where the Nansen net, as usual, has caught much more than the Hensen, but where it has not caught more than the average of the three open tow-nets in the water above, but still when the constitution of the catch is analysed it is noted that most of the Diatoms are in the Nansen and Hensen nets, and that the greater bulk of the catches from the upper layers of water is made up of Copepoda and other larger organisms.

It is rare for the Hensen net to catch more than the Nansen, but an example of that is seen on Form **45**, p. 126. The slight difference in bulk (0·5 c.c.) is, however, probably due in this case to the presence of a few Copepoda, Medusae and Oikopleura, and is thus of an accidental or non-significant nature. Form **41** on p. 129 shows what we consider to be a fairly representative series

of catches on an off-shore station, the Nansen being greater than the Hensen and the three open nets being greater still, while the weight net has caught more again than those on the surface. Form **42** on the second off-shore station at the same date shows a very similar proportion between the catches. Many other similar examples might be given. On the other hand, there are cases, such as station III on April 4th, when the Hensen and Nansen brought up such enormous quantities of Diatoms from the lower zone of water as to outnumber many times over the catch of all the other nets put together. On this occasion, the Hensen nets caught 64·5 c.c. and the Nansen 164 c.c., and several numbers of individual species of Diatoms in a single net run into millions, *Chaetoceros contortum* being estimated at fifteen millions in the Nansen net. On the following day at the second off-shore station the number of that Diatom is estimated at fourteen millions and the total amount in the Nansen net was 100 c.c., while the Hensen had only 12·5 c.c. The surface nets were 9 and 12 respectively, and the weighted net 15·5 c.c.

Although the numbers are not so high in the case of other groups, the same general principle holds later in April, when the Diatoms are disappearing and the Copepods are more abundant. We find that the Nansen net still obtains a much larger catch, and that the bulk of it is then made up of adult and larval Copepoda. For example, on April 22nd, at off-shore station I, the Nansen catch was 6 c.c. and the Hensen 1 c.c. The Nansen had 2,250 Copepoda and the Hensen 185; the Nansen had 15,000 Copepod Nauplii, and the Hensen 3,000; the Nansen had 1,500 later Copepod larvae, and the Hensen had 250; the Nansen had 1,000 Oikopleura, and the Hensen 125. Many other similar examples might be given.

One of our objects throughout this work was to sample the various layers of water, as well as to compare neighbouring localities and adjoining dates, and the following diagrammatic statement of certain of the hauls taken on September 12th will illustrate that part of the plan of the work: —

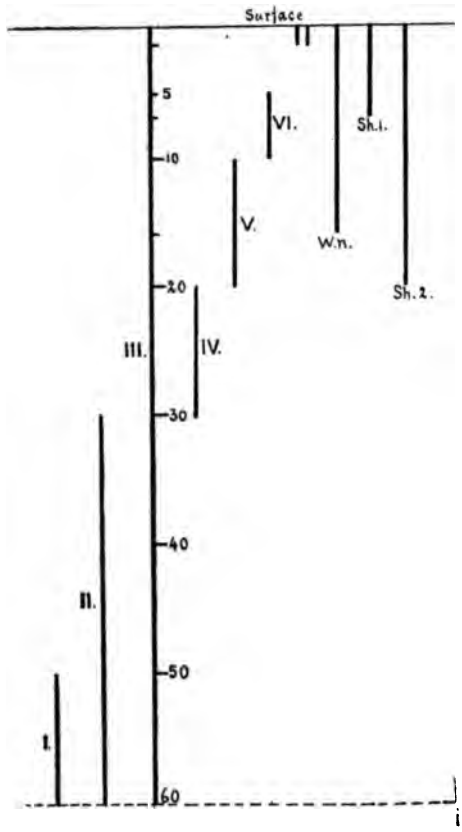


FIG. 5.—Diagram to show the hauls taken at one station. I.—VI. represent hauls of the vertical closing nets; W.n. (weight net), Sh. 1 and Sh. 2 (shear net) and the two surface nets represent horizontal or oblique hauls. The numbers 5 to 60 indicate depths in fathoms.

Here, out in the middle of the channel between Ireland and the Isle of Man, the depth was about 65 fathoms, and we sank our vertical nets down to 60, and hauled them up through the lower ten fathoms (I), the lower thirty (II), and the entire depth (III), then through the zones 30 to 20 (IV), twenty to ten (V), and ten to five (VI). That brought us in touch with the surface zone through which the weight-net, the shear-nets and the surface-nets had ranged. In this way we hoped to be able to localise the constituents of the fauna obtained in a vertical haul such as III.

It is clear that much further work in this direction is needed. Some of these serial hauls support the idea that there is a definite zone beneath the surface holding the maximum of organisms; but other hauls again seem to give contradictory evidence. For example, in the Hensen net hauls represented in the diagram (fig. 5) dealing with September 12th, Hensen I and Hensen II and Hensen IV all contained very small quantities of material, 0·1 c.c., each, while Hensen VI contained a very little more, 0·15 c.c. Hensen III, open all the way from the bottom to the surface, contained distinctly more material, 0·25 c.c., and Hensen VI drawn through a narrow zone of five fathoms only (ten to five fathoms) contained as much as Hensen III, indicating that most of the organisms were on this occasion contained in this narrow zone between five and ten fathoms. The Nansen hauls, on the other hand, did not bear this out, No. II and No. V containing more than either III or VI.

We feel that we have not yet sufficient data as to these serial vertical hauls to make it possible to discuss the matter of zonal distribution further at present.

## DISCUSSION OF THE GROUPS.

Turning now to the details of the various groups of organisms in the different hauls throughout the year we have, first of all, taken out the numbers of these groups from the lists day by day, dividing the totals by the number of hauls of the nets made on that day, so as to get results for each group, per day, per net. We have treated in that way the Diatoms, the Dinoflagellates, the Copepoda, the Cladocera, and a few of the more prominent single species such as *Ceratium tripos*, *Sagitta bipunctata*, *Tomopteris onisciformis*, *Oikopleura dioica*, and some of the Copepoda.

### Diatoms.

The variation in the total catch of Diatoms throughout the year will be seen from the following list. All the days upon which plankton gatherings were taken are recorded, and the Diatoms from all nets on each day are added together, the average per net for that day being given in the last column.

| | | Nets. | Total. | Average per net. |
|---|---|---|---|---|
| Jan. | 8 | 1 = | 5,650 | 5,650 |
| | 18 | 1 = | 34,300 | 34,300 |
| Feb. | 5 | 1 = | 152,600 | 152,600 |
| | 22 | 1 = | 205,050 | 205,050 |
| | 26 | 4 = | 293,900 | 73,475 |
| Mar. | 4 | 3 = | 284,000 | 94,666 |
| | 26 | 2 = | 220,000 | 110,000 |
| | 27 | 1 = | 277,000 | 277,000 |
| | 29 | 1 = | 326,000 | 101,330 |
| | 29 | 4 = | 180,650 | |
| Apr. | 1 | 5 = | 425,000 | 118,500 |
| | 1 | 3 = | 523,000 | |
| | 2 | 4 = | 1,000,000 | 250,000 |
| | 3 | 1 = | 335,000 | 335,000 |
| | 4 | 4 = | 890,000 | 2,369,333 |
| | 4 | 5 = | 20,434,000 | |
| | 5 | 5 = | 17,669,000 | 3,533,800 |
| | 6 | 2 = | 697,500 | 348,750 |
| | 8 | 5 = | 12,362,000 | 1,720,600 |
| | 8 | 5 = | 4,844,000 | |
| | 9 | 5 = | 1,249,000 | 200,429 |
| | 9 | 5 = | 696,000 | |
| | 9 | 2 = | 159,000 | |
| | 9 | 2 = | 702,000 | |

| | | | Nets. | Total. | | Average per net. |
|---|---|---|---|---|---|---|
| Apr. | 10 | ... | 2 = | 247,000 | | |
| | 10 | ... | 5 = | 3,662,000 | | |
| | 10 | ... | 5 = | 324,000 | ... | 297,706 |
| | 10 | ... | 3 = | 414,000 | | |
| | 10 | ... | 2 = | 414,000 | | |
| | 11 | ... | 5 = | 2,533,000 | | |
| | 11 | ... | 3 = | 514,000 | ... | 380,875 |
| | 13 | ... | 5 = | 2,269,000 | | |
| | 13 | ... | 3 = | 162,000 | | |
| | 13 | ... | 5 = | 410,000 | ... | 204,867 |
| | 13 | ... | 2 = | 232,000 | | |
| | 15 | ... | 5 = | 319,000 | | |
| | 15 | ... | 5 = | 528,000 | ... | 93,727 |
| | 15 | ... | 1 = | 184,000 | | |
| | 16 | ... | 5 = | 352,000 | | |
| | 16 | ... | 6 = | 107,000 | | |
| | 16 | ... | 3 = | 88,000 | ... | 44,600 |
| | 16 | ... | 1 = | 122,000 | | |
| | 17 | ... | 1 = | 215,000 | ... | 215,000 |
| | 18 | ... | 6 = | 371,000 | | |
| | 18 | ... | 5 = | 377,000 | | |
| | 18 | ... | 2 = | 9,000 | ... | 59,286 |
| | 18 | ... | 1 = | 73,000 | | |
| | 19 | ... | 5 = | 300,000 | | |
| | 19 | ... | 5 = | 458,000 | ... | 74,455 |
| | 19 | ... | 1 = | 61,000 | | |
| | 22 | ... | 5 = | 1,700 | | |
| | 22 | ... | 5 = | 1,400 | ... | 600 |
| | 22 | ... | 1 = | 3,500 | | |
| | 23 | ... | 3 = | 1,500 | | |
| | 23 | ... | 5 = | 4,300 | | |
| | 23 | ... | 3 = | 1,300 | ... | 1,342 |
| | 23 | ... | 1 = | 9,000 | | |
| | 24 | ... | 4 = | 2,663,000 | | |
| | 24 | ... | 5 = | 1,452 | | |
| | 24 | ... | 5 = | 211,000 | ... | 191,873 |
| | 24 | ... | 1 = | 2,650 | | |
| | 25 | ... | 5 = | 6,200 | | |
| | 25 | ... | 5 = | 900 | | |
| | 25 | ... | 4 = | 1,500 | ... | 663 |
| | 25 | ... | 1 = | 1,350 | | |
| | 26 | ... | 6 = | 200,000 | | |
| | 26 | ... | 5 = | 3,530 | ... | 16,982 |
| | 26 | ... | 1 = | 250 | | |
| | 27 | ... | 5 = | 64,000 | | |
| | 27 | ... | 6 = | 51,000 | | |
| | 27 | ... | 5 = | 202,000 | ... | 16,890 |
| | 27 | ... | 5 = | 6,770 | | |
| | 27 | ... | 1 = | 47,800 | | |
| May | 8 | ... | 1 = | 238,650 | ... | 238,650 |
| | 18 | ... | 1 = | 15,250 | ... | 15,250 |
| | 24 | ... | 1 = | 39,650 | ... | 39,650 |
| June | 11 | ... | 1 = | 103,000 | ... | 103,000 |
| | 15 | ... | 1 = | 8,500 | ... | 8,500 |
| | 27 | ... | 1 = | 6,075 | ... | 6,075 |
| July | 5 | ... | 1 = | 61,475 | ... | 61,475 |
| | 12 | ... | 1 = | 47,450 | ... | 47,450 |
| | 17 | ... | 1 = | 44,450 | ... | 44,450 |
| | 31 | ... | 1 = | 50 | ... | 50 |
| Aug. | 9 to 20.—No Diatoms. | | | | | |
| | 21 | ... | 6 = | 25 | ... | 6 |
| | 21 | ... | 5 = | 40 | | |

| | | | Nets. | | Total. | | Average per net. |
|---|---|---|---|---|---|---|---|
| Aug. | 23 | ... | 3 | = | 4 | | |
| | 23 | ... | 4 | = | 60 | ... | 8 |
| | 23 | ... | 5 | = | 30 | | |
| | 24 | ... | 3 | = | 70 | | |
| | 24 | ... | 5 | = | 340 | | |
| | 24 | ... | 4 | = | 6,060 | ... | 425 |
| | 24 | ... | 7 | = | 1,600 | | |
| | 26 | ... | 6 | = | 580 | | |
| | 26 | ... | 6 | = | 105 | ... | 57 |
| | 27 | ... | 3 | = | 400 | ... | 133 |
| | 28 | ... | 6 | = | 3,270 | | |
| | 28 | ... | 8 | = | 1,480 | ... | 339 |
| | 29 | ... | 5 | = | 4,055 | ... | 811 |
| | 30 | ... | 1 | = | 250 | ... | 250 |
| | 31 | ... | 12 | = | 2,610 | ... | 217 |
| Sept. | 2 | ... | 6 | = | 460 | ... | 76 |
| | 3 | ... | 3 | = | 2,475 | | |
| | 3 | ... | 8 | = | 5,485 | ... | 724 |
| | 4 | ... | 9 | = | 3,000 | | |
| | 4 | ... | 5 | = | 4,528 | | |
| | 4 | ... | 5 | = | 3,400 | ... | 575 |
| | 6 | ... | 9 | = | 2,600 | | |
| | 6 | ... | 9 | = | 6,484 | | |
| | 6 | ... | 9 | = | 1,445 | ... | 390 |
| | 9 | ... | 3 | = | 28,400 | ... | 9,467 |
| | 10 | ... | 7 | = | 6,340 | ... | 906 |
| | 11 | ... | 8 | = | 3,900 | | |
| | 11 | ... | 8 | = | 4,925 | | |
| | 11 | ... | 8 | = | 9,000 | ... | 743 |
| | 12 | ... | 8 | = | 29,960,000 | | |
| | 12 | ... | 8 | = | 70,000 | | |
| | 12 | ... | 3 | = | 5,000,000 | ... | 1,843,684 |
| | 13 | ... | 3 | = | 2,980 | ... | 993 |
| | 14 | ... | 1 | = | 1,600 | ... | 1,600 |
| | 16 | ... | 7 | = | 5,658 | ... | 808 |
| | 17 | ... | 7 | = | 55,000 | | |
| | 17 | ... | 7 | = | 25,000 | ... | 5,714 |
| | 18 | ... | 7 | = | 2,777 | | |
| | 18 | ... | 8 | = | 16,000 | ... | 1,252 |
| | 19 | ... | 8 | = | 12,317 | ... | 1,539 |
| | 20 | ... | 9 | = | 4,245,000 | | |
| | 20 | ... | 9 | = | 88,000 | | |
| | 20 | ... | 9 | = | 558,000 | ... | 477,664 |
| | 20 | ... | 5 | = | 10,394,250 | | |
| | 21 | ... | 1 | = | 8,000 | ... | 8,000 |
| | 23 | ... | 1 | = | 11,550 | ... | 11,550 |
| | 24 | ... | 1 | = | 31,950 | ... | 31,950 |
| | 26 | ... | 1 | = | 103,655 | ... | 103,655 |
| | 27 | ... | 1 | = | 128,350 | ... | 128,350 |
| | 28 | ... | 1 | = | 156,150 | ... | 156,150 |
| | 30 | ... | 1 | = | 579,250 | .. | 579,250 |
| Oct. | 1 | ... | 1 | = | 91,050 | ... | 91,050 |
| | 9 | ... | 1 | = | 2,450 | ... | 2,450 |
| | 14 | ... | 1 | = | 0 | ... | 0 |
| | 24 | ... | 1 | = | 3,500 | ... | 3,500 |
| Nov. | 4 | ... | 1 | = | 6,530 | ... | 6,530 |
| | 8 | ... | 1 | = | 159,300 | ... | 159,300 |
| | 16 | ... | 1 | = | 26,685 | ... | 26,685 |
| | 25 | ... | 1 | = | 75,075 | ... | 75,075 |
| Dec. | 12 | ... | 1 | = | 13,820 | ... | 13,820 |
| | 20 | ... | 1 | = | 11,450 | ... | 11,450 |
| | 23 | ... | 1 | = | 6,950 | ... | 6,950 |
| | 30 | ... | 1 | = | 8,000 | ... | 8,000 |

From these daily averages a three-days' average has now been made, with results as follows:—

| Nets | | Daily Average | 3-daily Average |
|---|---|---|---|
| 2. | Mar. 26— | 110,000 | — |
| 1. | 27— | 277,000 | 162,777 |
| 5. | 29— | 101,330 | 165,610 |
| 8. | April 1— | 118,500 | 156,610 |
| 4. | 2— | 250,000 | 234,500 |
| 1. | 3— | 335,000 | 738,583 |
| 9. | 4— | 2,369,333 | 2,079,378 |
| 5. | 5— | 3,533,800 | 2,083,961 |
| 2. | 6— | 348,750 | 1,867,717 |
| 10. | 8— | 1,720,600 | 756,593 |
| 14. | 9— | 200,429 | 739,578 |
| 17. | 10— | 297,706 | 326,345 |
| 8. | 11— | 380,900 | 294,491 |
| 15. | 13— | 204,867 | 226,498 |
| 11. | 15— | 93,727 | 114,398 |
| 15. | 16— | 44,600 | 114,442 |
| 1. | 17— | 215,000 | 106,295 |
| 14. | 18— | 59,286 | 116,247 |
| 11. | 19— | 74,455 | 44,780 |
| 11. | 22— | 600 | 25,466 |
| 12. | 23— | 1,342 | 64,605 |
| 15. | 24— | 191,873 | 64,626 |
| 15. | 25— | 663 | 69,839 |
| 12. | 26— | 16,982 | 11,512 |
| 22. | 27— | 16,890 | — |
| | Aug. 20— | — | 2 |
| 11. | 21— | 6 | 2 |
| | 22— | — | 5 |
| 12. | 23— | 8 | 144 |
| 19. | 24— | 425 | 163 |
| 12. | Aug. 26— | 57 | 205 |
| 3. | 27— | 133 | 176 |
| 14. | 28— | 339 | 428 |
| 5. | 29— | 811 | 467 |
| 1. | 30— | 250 | 426 |
| 12. | 31— | 217 | 181 |
| 6. | Sept. 2— | 76 | 339 |
| 11. | 3— | 724 | 458 |
| 19. | 4— | 575 | 563 |
| 27. | 6— | 390 | 3,477 |
| 3. | 9— | 9,467 | 3,588 |
| 7. | 10— | 906 | 3,705 |
| 24. | 11— | 743 | 615,111 |
| 19. | 12— | 1,843,684 | 615,140 |
| 3. | 13— | 993 | 615,426 |
| 1. | 14— | 1,600 | 1,134 |
| 7. | 16— | 808 | 2,707 |
| 14. | 17— | 5,714 | 2,591 |
| 15. | 18— | 1,252 | 2,835 |
| 8. | 19— | 1,539 | 160,152 |
| 32. | 20— | 477,664 | 162,401 |
| 1. | 21— | 8,000 | 165,738 |
| 1. | 23— | 11,550 | 17,167 |
| 1. | 24— | 31,950 | 49,052 |
| 1. | 26— | 103,655 | 88,652 |
| 1. | 27— | 130,350 | 120,785 |
| 1. | 28— | 128,350 | 279,317 |
| 1. | 30— | 579,250 | 266,217 |
| 1. | Oct. 1— | 91,050 | — |

On considering this list, the following points come out:—The average number of Diatoms per catch often varies considerably from day to day, as will be seen by a glance at the table. Thus on April 5th the average of all catches of that day was 3,533,800, while on April 6th it fell to 348,750; on April 24th it was 191,873, while on April 25th it was only 663. Again, on September 10th and 11th it was 906 and 743 respectively, but rose to 1,843,684 on the following day; on September 19th it was 1,539, while on September 20th it was 477,664.

Each of the above numbers, however, is the average of several catches, that is of all the nettings taken during

a single day, and they do not by any means give an adequate idea of the quantitative variation among individual catches. Thus on September 10th surface nets I and II contained 250 and 550 respectively, while two days later the corresponding numbers were 13,495,500 and 16,300,500; on April 8th two hauls of the Nansen net gave respectively 198,000 and 3,739,000, and many other such cases could be quoted.

Such differences as above cited are due in the main to the great abundance of some single organism, generally *Rhizosolenia semispina*, *Chaetoceros contortum*, *C. debile* or *Thalassiosira nordenskioldii*. Thus of the two enormous surface nettings of September 12th given above, *Rhizosolenia semispina* accounts for thirteen millions and sixteen millions of the organisms respectively; again the high average (477,664) of 32 hauls made on September 20th is traceable largely to the influence of four of the catches amounting together to 13,230,150, of which 13,085,000 were *Rhizosolenia semispina*.

Besides, however, these great fluctuating changes it will be seen that there is a more regular seasonal change. This is brought out more clearly by the diagram (p. 177). Owing to the frequency of the spring and autumn hauls it is possible to take 3-daily averages from March 27th to April 26th, and again from August 20th to September 30th, but it should be noted that while the spring catches and those of the middle (August 23rd to September 19th) of the autumn period were made with several kinds of nets outside the Bay, together with surface nets within the Bay, those on other occasions were made only by the surface nets within the Bay; at other times than the above two periods the nettings numbered from three to four per month.

The curve shows two humps, a well-marked one in

early April and a less conspicuous one during the latter half of September.

The spring hump rises suddenly and falls again almost as suddenly, the main portion occupying about three weeks (the last week in March and the first fortnight in April). It is to be noted that its height is largely influenced by the catches of three days, namely, April 4th (2,369,333), April 5th (3,533,800) and April 8th (1,720,600), which were due mainly to the large numbers of *Chaetoceros contortum*, *C. debile* and *Thalassiosira nordenskioldii* in certain of the nettings included. Omitting these three days, however, the curve retains the same general character as before, except that the peak is very materially reduced.

The autumn hump is not so well marked, in fact if the catches of the three days, September 12th, 20th and 30th, be omitted it almost entirely disappears and is confined to the last week in September; it depends, moreover, entirely upon surface nettings taken in the Bay.

At other times of the year the catches were small, reaching, however, about 200,000 now and then sporadically. The minima were during August, October and December, in particular from August 9th to August 20th, when no Diatoms were taken, though surface nettings were made (within the Bay) on all the days with two exceptions.

### Dinoflagellata.

The following list of the Dinoflagellata throughout the year is drawn up on exactly the same lines as that for the Diatoms.

| | Nets. | Total. | Average per Net. |
|---|---|---|---|
| Jan. 8 ... | 1 = | 0 ... | 0 |
| 18 ... | 1 = | 100 ... | 100 |
| Feb. 5 ... | 1 = | 1,400 ... | 1,400 |

| | | Nets. | | Total. | | Average per Net. |
|---|---|---|---|---|---|---|
| Feb. 22 | ... | 1 | = | 750 | ... | 750 |
| 26 | ... | 4 | = | 300 | ... | 75 |
| Mar. 4 | ... | 3 | = | 0 | ... | 0 |
| 26 | ... | 2 | = | 4,000 | ... | 2,000 |
| 29 | ... | 5 | = | 7,900 | ... | 1,580 |
| April 1 | ... | 8 | = | 14,900 | ... | 1,862 |
| 2 | ... | 4 | = | 3,500 | ... | 875 |
| 4 | ... | 9 | = | 5,700 | ... | 633 |
| 5 | ... | 5 | = | 16,500 | ... | 3,300 |
| 6 | ... | 2 | = | 3,600 | ... | 1,800 |
| 8 | ... | 10 | = | 30,050 | ... | 3,005 |
| 9 | ... | 14 | = | 79,850 | ... | 5,704 |
| 10 | ... | 17 | = | 84,350 | ... | 4,962 |
| 11 | ... | 8 | = | 12,500 | ... | 1,562 |
| 13 | ... | 15 | = | 29,350 | ... | 1,957 |
| 15 | ... | 11 | = | 36,450 | ... | 3,313 |
| 16 | ... | 15 | = | 31,245 | ... | 2,083 |
| 17 | ... | 1 | = | 4,500 | ... | 4,500 |
| 18 | ... | 14 | = | 38,125 | ... | 2,723 |
| 19 | ... | 11 | = | 43,700 | ... | 3,972 |
| 22 | ... | 11 | = | 7,895 | ... | 717 |
| 23 | ... | 12 | = | 11,100 | ... | 925 |
| 24 | ... | 15 | = | 49,259 | ... | 3,284 |
| 25 | ... | 15 | = | 14,248 | ... | 950 |
| 26 | ... | 14 | = | 39,735 | ... | 2,838 |
| 27 | ... | 18 | = | 32,255 | ... | 1,792 |
| May 8 | ... | 1 | = | 3,575 | ... | 3,575 |
| 18 | ... | 1 | = | 1,850 | ... | 1,850 |
| 24 | ... | 1 | = | 3,000 | ... | 3,000 |
| June 11 | ... | 1 | = | 5,000 | ... | 5,000 |
| 15 | ... | 1 | = | 375 | ... | 375 |
| 27 | ... | 1 | = | 3,000 | ... | 3,000 |
| July 5 | ... | 1 | = | 2,575 | ... | 2,575 |
| 12 | ... | 1 | = | 3,375 | ... | 3,375 |
| 17 | ... | 1 | = | 8,000 | ... | 8,000 |
| 31 | ... | 1 | = | 3,750 | ... | 3,750 |
| Aug. 9 | ... | 1 | = | 0 | ... | 0 |
| 10 | ... | 1 | = | 1,000 | ... | 1,000 |
| 12 | ... | 1 | = | 2,000 | ... | 2,000 |
| 13 | ... | 1 | = | 2,000 | ... | 2,000 |
| 14 | ... | 1 | = | 1,000 | ... | 1,000 |
| 15 | ... | 1 | = | 1,000 | ... | 1,000 |
| 16 | ... | 1 | = | 500 | ... | 500 |
| 17 | ... | 4 | = | 112 | ... | 28 |
| 19 | ... | 4 | = | 787 | ... | 197 |
| 20 | ... | 5 | = | 1,582 | ... | 316 |
| 21 | ... | 13 | = | 8,201 | ... | 631 |
| 22 | ... | 1 | = | 875 | ... | 875 |
| 23 | ... | 15 | = | 3,244 | ... | 216 |
| 24 | ... | 19 | = | 5,250 | ... | 276 |
| 26 | ... | 12 | = | 1,190 | ... | 99 |
| 27 | ... | 3 | = | 1,735 | ... | 578 |
| 28 | ... | 14 | = | 9,095 | ... | 650 |
| 29 | ... | 5 | = | 5,665 | ... | 1,133 |
| 30 | ... | 1 | = | 300 | ... | 300 |
| 31 | ... | 12 | = | 3,605 | ... | 300 |

| | | Nets. | Total. | Average per net. |
|---|---|---|---|---|
| Sept. | 2 | 6 = | 2,235 | 372 |
| | 3 | 11 = | 16,611 | 1,510 |
| | 4 | 19 = | 6,305 | 332 |
| | 5 | 1 = | 50 | 50 |
| | 6 | 26 = | 11,356 | 436 |
| | 9 | 3 = | 10,900 | 3,633 |
| | 10 | 7 = | 2,950 | 421 |
| | 11 | 24 = | 19,876 | 828 |
| | 12 | 19 = | 195,835 | 10,307 |
| | 13 | 3 = | 2,750 | 917 |
| | 14 | 1 = | 1,700 | 1,700 |
| | 16 | 8 = | 4,635 | 579 |
| | 17 | 14 = | 22,491 | 1,606 |
| | 18 | 15 = | 4,427 | 295 |
| | 19 | 9 = | 6,820 | 758 |
| | 20 | 36 = | 44,502 | 1,236 |
| | 21 | 1 = | 1,000 | 1,000 |
| | 23 | 1 = | 750 | 750 |
| | 24 | 1 = | 1,750 | 1,750 |
| | 26 | 1 = | 1,000 | 1,000 |
| | 27 | 1 = | 2,250 | 2,250 |
| | 28 | 1 = | 1,500 | 1,500 |
| | 30 | 1 = | 1,500 | 1,500 |
| Oct. | 1, 9, 14, 24 | 4 = | 0 | 0 |
| Nov. | 4 | 1 = | 225 | 225 |
| | 8 | 1 = | 200 | 200 |
| | 16 | 1 = | 600 | 600 |
| | 25 | 1 = | 1,125 | 1,125 |
| Dec. | 12 | 1 = | 470 | 470 |
| | 20 | 1 = | 650 | 650 |
| | 23 | 1 = | 300 | 300 |
| | 30 | 1 = | 600 | 600 |

From the above list of the Dinoflagellate catches, and the accompanying curve (compiled from a total of 595 hauls), it is seen that the numbers rise from a very low point at the beginning of the year to a series of peaks in April, the highest of which is 5,704 per haul on the 9th, and in July a higher point (8,000) is reached, after which the numbers fall and keep generally at a lower level until the middle of September, when for a single day a very high average is attained, 10,307, the highest in the year. After this there is a very rapid fall, the

group is unrepresented in October,* and the numbers keep irregular but low during November, December and January.

We have taken out separately from the statistics the figures in regard to *Ceratium tripos*, perhaps the most abundant species of Dinoflagellate in our district. It is

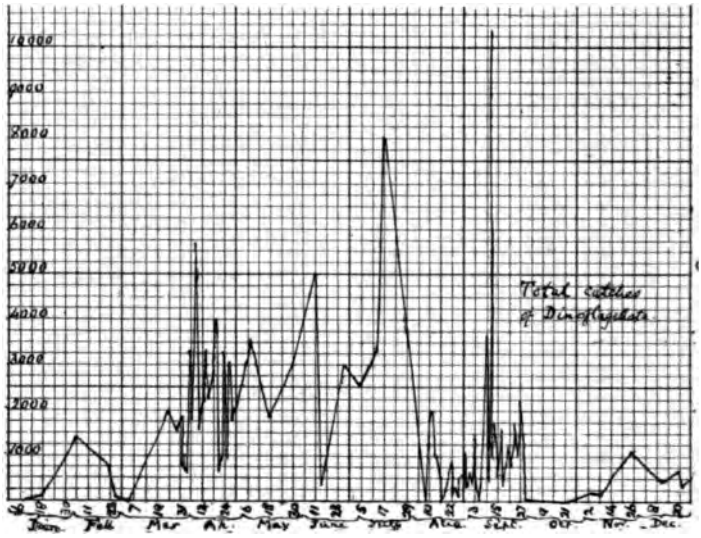


FIG. 6.

the more important that this should be done since a statement has appeared in a recent Blue-book (North Sea Fisheries Investigation Committee: Second Report (Southern Area) Part I, Cd. 3837, December, 1907, p. 172)

* That is unrepresented in the series of gatherings from the Manx seas which we are considering; but members of the group were certainly present in the Irish Sea during the month, as two species of *Ceratium* were taken by the Lancashire Sea-Fisheries steamer at three Stations East of the Isle of Man, on October 7th. I do not suppose that Dinoflagellates are ever totally absent from the Irish Sea in any month of the year. Gough has recorded (Blue-book, Cd. 3837, p. 263) two species of *Ceratium* and three species of *Peridinium* as being rarely, or very rarely, present in the gatherings from the Bahama Bank Lightship in 1904.

which may, if not corrected, give rise to a false impression. The Marine Biological Association obtain gatherings once a fortnight from certain light-ships on the west coast, and one of these (on the Bahama Bank) is in our district of the Irish Sea. On the basis of these fortnightly gatherings (23) at this one station, in the year (1904) under discussion, Dr. L. H. Gough states in the official Blue-book that "*Ceratium tripos* was never seen at Bahama Bank," and again, "In the Irish Sea it [*C. tripos*] was rarest or even absent at the northern stations" [that is at the Isle of Man]. From such statements one would certainly gather that the organism in question was very rare, if not altogether absent from our district; but the fact is that it occurs practically all the year round in considerable abundance off the Isle of Man. *Ceratium tripos* is regarded as an oceanic species, and it is stated to have been found "very frequently" at Plymouth throughout 1904, but as no numbers are given in the detailed tables of the Blue-book (but merely crosses which indicate the presence, or in some cases letters to indicate relative abundance), it is impossible to compare results and to say whether our recorded figures for the Irish Sea are greater or less than the numbers of this organism found in the English Channel. And yet from the fortnightly gatherings from certain light-ships (one of which is in our district), in which certain organisms were not found, the far-reaching conclusion is drawn that "on the whole the Irish Sea may be said to be more neritic [i.e., showing a scarcity of oceanic species] than the Channel" (p. 169). That *may* be the case, but the conclusion can scarcely be based upon such statistics as the North Sea Fisheries Investigation Committee put forth in their official Blue-book. The facts in regard to this "oceanic" species *Ceratium tripos* are:—

(1) Their 28 gatherings in one year did not show the organism to be present.

(2) Our 650 gatherings in one year showed that it was present during eleven months, and was fairly abundant (up to 7,753 per haul) during most of the year.

In the following list we have separated the records of *Ceratium tripos* within Port Erin Bay from those taken in the open sea, and we give a curve for each locality (fig. 7). In most cases where hauls were taken in both places at the same time a larger number of individuals occurred within the bay; but on the other hand the largest number collected (7,753, on September 12th) was in a haul from the open sea.

Distribution of *Ceratium tripos*, per net, throughout the year:—

| | Bay. | Open Sea. |
|---|---|---|
| Jan. 18 | 100 | — |
| Feb. 5 | 900 | — |
| 22 | 750 | — |
| 26 | 300 | — |
| Mar. 26 | 500 | — |
| 29 | 3,000 | 1,000 |
| April 1 | — | 1,900 |
| 2 | — | 2,000 |
| 4 | — | 550 |
| 5 | — | 1,622 |
| 6 | 500 | — |
| 8 | — | 590 |
| 9 | 2,750 | 1,119 |
| 10 | 1,850 | 1,310 |
| 11 | — | 1,125 |
| 13 | 3,000 | 300 |
| 15 | 300 | 633 |
| 16 | 1,000 | 709 |
| 17 | 3,000 | — |
| 18 | 2,000 | 469 |
| 19 | — | 792 |
| 22 | 2,000 | 188 |
| 23 | 1,000 | 250 |
| 24 | 750 | 1,049 |
| 25 | 250 | 412 |
| 26 | 250 | 529 |
| 27 | 1,125 | 659 |
| May 8 | 1,000 | — |
| 18 | 1,750 | — |
| 24 | 2,000 | — |
| June 11 | 1,500 | — |
| 15 | 300 | — |
| 27 | 2,000 | — |
| July 5 | 375 | — |
| 12 | 2,500 | — |
| 17 | 4,375 | — |
| 31 | 2,750 | — |
| Aug. 10 | 1,000 | — |
| 12 | 2,000 | — |
| 13 | 2,000 | — |
| 14 | 1,000 | — |
| 15 | 1,000 | — |
| 16 | 500 | — |
| 17 | 100 | — |
| 19 | 375 | — |
| 20 | 500 | — |
| 21 | 37 | 725 |
| 22 | 800 | — |
| 23 | 325 | 142 |
| 24 | — | 147 |
| 26 | — | 75 |
| 27 | — | 383 |
| 28 | 400 | 716 |
| 29 | — | 98 |
| 30 | 300 | — |
| 31 | 150 | 375 |
| Sept. 2 | — | 290 |
| 3 | 2,200 | 1,028 |
| 4 | — | 289 |
| 5 | 50 | — |

| | Bay. | Open Sea. | | Bay. | Open Sea. |
|---|---|---|---|---|---|
| Sept. 6 ... | — ... | 373 | Sept. 24 ... | 1,500 ... | — |
| 9 ... | — ... | 2,867 | 26 ... | 750 ... | — |
| 10 ... | 800 ... | 290 | 27 ... | 1,250 ... | — |
| 11 ... | — ... | 761 | 28 ... | 1,000 ... | — |
| 12 ... | — ... | 7,753 | 30 ... | 1,500 ... | — |
| 13 ... | 150 ... | — | [Oct. ... | none ... | none] |
| 14 ... | 1,600 ... | — | Nov. 4 ... | 225 ... | — |
| 16 ... | 1,250 ... | 425 | 8 ... | 200 ... | — |
| 17 ... | — ... | 1,000 | 16 ... | 375 ... | — |
| 18 ... | 875 ... | 357 | 25 ... | 875 ... | — |
| 19 ... | 900 ... | 460 | Dec. 12 ... | 325 ... | — |
| 20 ... | 150 ... | 1,102 | 20 ... | 600 ... | — |
| 21 ... | 1,000 ... | — | 22 ... | 300 ... | — |
| 23 ... | 750 ... | — | 30 ... | 600 ... | — |

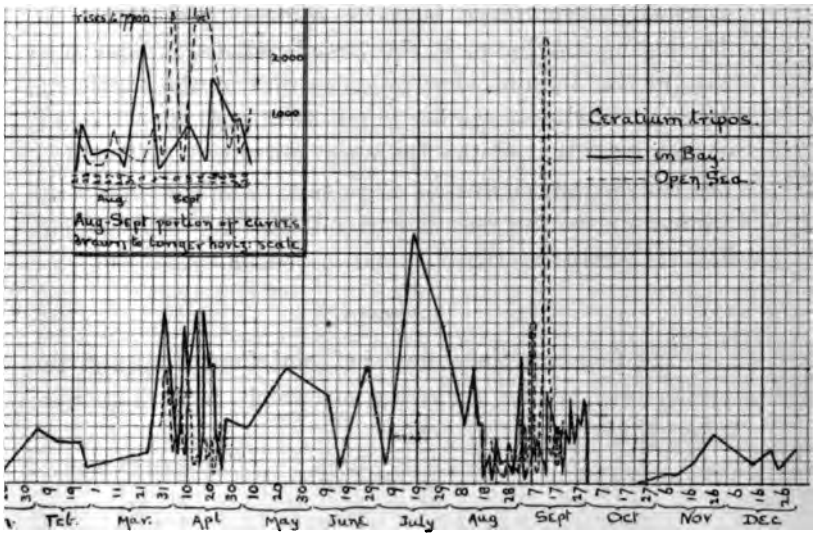


Fig. 7.

The general impression received from an inspection of these numbers is their constancy—a large proportion of them lie between 1,000 and 3,000; in the middle of April we see a run of 3,000, 1,000, 3,000, 2,000, 2,000, 1,000; in May, 1,000, 1,750, 2,000; in August, 1,000, 2,000, 2,000, 1,000, 1,000, and so on; and then again in November and December we have a run of hundreds, from

225 on November 4th to 600 on December 30th. All these numbers represent single hauls of a net.

The curve for the open sea can only be drawn for April and for portions of August and September; but during these periods it agrees fairly well with the curve for the bay. It shows the same kind of variations, up and down, although in April the humps do not reach so high and in September they go a great deal higher.

The curve for *Ceratium tripos* agrees in general with that for the total Dinoflagellates (fig. 6), but differs markedly from those both of Diatoms and Copepoda. The spring maximum in the Dinoflagellates is later than that of the Diatoms, but precedes that of the Copepoda. Then again the September hump of the Dinoflagellates is earlier than that of the Diatoms, and much earlier than the October maximum of Copepoda. On the whole the annual curve for the Dinoflagellates lies intermediate between those for Diatoms and Copepoda.

### Copepoda.

The following list shows the Total Copepoda, and the average per net for each day on which gatherings were taken throughout the year.

| | Nets. | Total. | Average per Net. |
|---|---|---|---|
| Jan. 8 | 1 = | 2,082 | 2,082 |
| 18 | 1 = | 1,551 | 1,551 |
| Feb. 5 | 1 = | 1,110 | 1,110 |
| 22 | 1 = | 30 | 30 |
| 26 | 1 = | 1,238 | 1,238 |
| Mar. 4 | 1 = | 1,825 | 1,825 |
| 26 | 2 = | 587 | 294 |
| 27 | 1 = | 476 | 476 |
| 29 | 1 = | 3,210 | 3,210 |
| 29 | 4 = | 4,370 | 1,092 |
| April 1 | 8 = | 26,495 | 3,312 |
| 2 | 4 = | 18,000 | 4,500 |
| 4 | 9 = | 1,135 | 126 |
| 4 | 4 = | 2,234 | 558 |
| 5 | 5 = | 2,247 | 449 |
| 6 | 2 = | 6,873 | 3,436 |
| 8 | 10 = | 4,135 | 413 |
| 9 | 2 = | 2,183 | 1,091 |

| | | Nets. | | Total. | | Average per Net. |
|---|---|---|---|---|---|---|
| April | 9 | ... | 12 = | 42,915 | ... | 3,576 |
| | 10 | ... | 2 = | 4,679 | ... | 2,339 |
| | 10 | ... | 15 = | 18,349 | ... | 1,223 |
| | 11 | ... | 8 = | 12,222 | ... | 1,528 |
| | 13 | ... | 2 = | 21,550 | ... | 10,775 |
| | 13 | ... | 13 = | 27,776 | ... | 2,136 |
| | 15 | ... | 1 = | 9,280 | ... | 9,280 |
| | 15 | ... | 10 = | 10,507 | ... | 1,050 |
| | 16 | ... | 1 = | 11,600 | ... | 11,600 |
| | 16 | ... | 14 = | 26,335 | ... | 1,881 |
| | 17 | ... | 1 = | 15,659 | ... | 15,659 |
| | 18 | ... | 1 = | 6,102 | ... | 6,102 |
| | 18 | ... | 13 = | 32,250 | ... | 2,481 |
| | 19 | ... | 1 = | 9,750 | ... | 9,750 |
| | 19 | ... | 11 = | 43,203 | ... | 3,927 |
| | 22 | ... | 1 = | 16,300 | ... | 16,300 |
| | 22 | ... | 11 = | 47,955 | ... | 4,359 |
| | 23 | ... | 1 = | 16,210 | ... | 16,210 |
| | 23 | ... | 11 = | 82,799 | ... | 7,527 |
| | 24 | ... | 1 = | 7,881 | ... | 7,881 |
| | 24 | ... | 11 = | 109,272 | ... | 9,934 |
| | 25 | ... | 1 = | 2,328 | ... | 2,328 |
| | 25 | ... | 14 = | 53,823 | ... | 3,844 |
| | 26 | ... | 1 = | 4,040 | ... | 4,040 |
| | 26 | ... | 14 = | 57,554 | ... | 4,111 |
| | 27 | ... | 2 = | 59,650 | ... | 29,825 |
| | 27 | ... | 17 = | 48,360 | ... | 2,845 |
| May | 8 | ... | 1 = | 1,045 | ... | 1,045 |
| | 18 | ... | 1 = | 2,695 | ... | 2,695 |
| | 24 | ... | 1 = | 6,505 | ... | 6,505 |
| June | 11 | ... | 1 = | 13,610 | ... | 13,610 |
| | 15 | ... | 1 = | 7,355 | ... | 7,355 |
| | 27 | ... | 1 = | 15,450 | ... | 15,450 |
| July | 5 | ... | 1 = | 6,680 | ... | 6,680 |
| | 12 | ... | 1 = | 2,895 | ... | 2,895 |
| | 17 | ... | 1 = | 7,930 | ... | 7,930 |
| | 31 | ... | 1 = | 4,345 | ... | 4,345 |
| Aug. | 9 | ... | 1 = | 9,450 | ... | 9,450 |
| | 10 | ... | 1 = | 18,200 | ... | 18,200 |
| | 12 | ... | 1 = | 9,700 | ... | 9,700 |
| | 13 | ... | 1 = | 6,200 | ... | 6,200 |
| | 13 | ... | 1 = | 1,851 | ... | 1,851 |
| | 14 | ... | 1 = | 19,400 | ... | 19,400 |
| | 15 | ... | 1 = | 14,700 | ... | 14,700 |
| | 16 | ... | 1 = | 8,801 | ... | 8,801 |
| | 16 | ... | 1 = | 640 | ... | 640 |
| | 17 | ... | 4 = | 28,961 | ... | 7,240 |
| | 19 | ... | 4 = | 5,499 | ... | 1,375 |
| | 20 | ... | 5 = | 13,057 | ... | 2,611 |
| | 21 | ... | 2 = | 114 | ... | 57 |
| | 21 | ... | 6 = | 27,138 | ... | 4,523 |
| | 21 | ... | 5 = | 11,070 | ... | 2,214 |
| | 21 | ... | 3 = | 5,306 | ... | 1,768 |
| | 22 | ... | 1 = | 2,600 | ... | 2,600 |
| | 23 | ... | 2 = | 9,336 | ... | 4,668 |
| | 23 | ... | 3 = | 4,811 | ... | 1,604 |
| | 23 | ... | 4 = | 12,035 | ... | 3,009 |
| | 23 | ... | 5 = | 9,842 | ... | 1,968 |
| | 23 | ... | 3 = | 648 | ... | 216 |
| | 24 | ... | 3 = | 27,086 | ... | 9,028 |

| | | | Nets. | | Total. | | Average per Net. |
|---|---|---|---|---|---|---|---|
| Aug. | 24 | ... | 5 | = | 84,577 | ... | 16,915 |
| | 24 | ... | 4 | = | 462 | ... | 115 |
| | 24 | ... | 7 | = | 7,079 | ... | 1,011 |
| | 26 | ... | 6 | = | 2,822 | ... | 470 |
| | 26 | ... | 6 | = | 52,981 | ... | 8,830 |
| | 27 | ... | 3 | = | 29,906 | ... | 9,968 |
| | 28 | ... | 6 | = | 23,187 | ... | 3,864 |
| | 28 | ... | 8 | = | 9,787 | ... | 1,223 |
| | 29 | ... | 5 | = | 54,850 | ... | 10,970 |
| | 30 | ... | 1 | = | 2,800 | ... | 2,800 |
| | 31 | ... | 6 | = | 2,825 | ... | 470 |
| | 31 | ... | 6 | = | 23,534 | ... | 3,922 |
| Sept. | 2 | ... | 6 | = | 20,403 | ... | 3,400 |
| | 3 | ... | 8 | = | 21,359 | ... | 2,669 |
| | 3 | ... | 3 | = | 2,325 | ... | 775 |
| | 4 | ... | 9 | = | 60,345 | ... | 6,705 |
| | 4 | ... | 5 | = | 14,820 | ... | 2,964 |
| | 4 | ... | 6 | = | 71,651 | ... | 11,942 |
| | 6 | ... | 9 | = | 1,779 | ... | 197 |
| | 6 | ... | 9 | = | 18,927 | ... | 2,103 |
| | 6 | ... | 9 | = | 23,390 | ... | 2,599 |
| | 9 | ... | 3 | = | 11,145 | ... | 3,715 |
| | 10 | ... | 7 | = | 14,579 | ... | 2,083 |
| | 11 | ... | 8 | = | 4,835 | ... | 604 |
| | 11 | ... | 8 | = | 57,882 | ... | 7,235 |
| | 11 | ... | 8 | = | 57,232 | ... | 7,154 |
| | 12 | ... | 8 | = | 3,034 | ... | 379 |
| | 12 | ... | 8 | = | 6,368 | ... | 796 |
| | 12 | ... | 3 | = | 81,531 | ... | 27,177 |
| | 13 | ... | 3 | = | 14,412 | ... | 4,804 |
| | 14 | ... | 1 | = | 3,595 | ... | 3,595 |
| | 16 | ... | 8 | = | 67,332 | ... | 8,416 |
| | 17 | ... | 7 | = | 14,025 | ... | 2,003 |
| | 17 | ... | 4 | = | 3,354 | ... | 838 |
| | 18 | ... | 8 | = | 55,595 | ... | 6,949 |
| | 18 | ... | 4 | = | 30,802 | ... | 7,700 |
| | 19 | ... | 9 | = | 43,877 | ... | 4,875 |
| | 20 | ... | 9 | = | 120,962 | ... | 13,440 |
| | 20 | ... | 9 | = | 2,434 | ... | 270 |
| | 20 | ... | 9 | = | 37,374 | ... | 4,152 |
| | 20 | ... | 5 | = | 136,561 | ... | 27,312 |
| | 21 | ... | 1 | = | 10,582 | ... | 10,582 |
| | 23 | ... | 1 | = | 18,450 | ... | 18,450 |
| | 24 | ... | 1 | = | 11,850 | ... | 11,850 |
| | 26 | ... | 1 | = | 2,197 | ... | 2,197 |
| | 27 | ... | 1 | = | 2,131 | ... | 2,131 |
| | 28 | ... | 1 | = | 8,325 | ... | 8,325 |
| | 30 | ... | 1 | = | 12,110 | ... | 12,110 |
| Oct. | 1 | ... | 1 | = | 1,045 | ... | 1,045 |
| | 9 | ... | 1 | = | 16,973 | ... | 16,973 |
| | 14 | ... | 1 | = | 27,790 | ... | 27,790 |
| | 24 | ... | 1 | = | 24,480 | ... | 24,480 |
| Nov. | 4 | ... | 1 | = | 5,587 | ... | 5,587 |
| | 8 | ... | 1 | = | 10,937 | ... | 10,937 |
| | 16 | ... | 1 | = | 3,853 | ... | 3,853 |
| | 25 | ... | 1 | = | 7,314 | ... | 7,314 |
| Dec. | 12 | ... | 1 | = | 1,724 | ... | 1,724 |
| | 20 | ... | 1 | = | 2,275 | ... | 2,275 |
| | 23 | ... | 1 | = | 2,403 | ... | 2,403 |
| | 30 | ... | 1 | = | 2,755 | ... | 2,755 |

The Copepoda have two maxima in the year, the first in April and the second in September and October. The records start in January with about 2,000 per haul and keep below that level throughout February and most of March. During April they rapidly mount up with a series of successively higher records, with falls between, such as April 2nd 4,500, April 13th 10,775, April 16th 11,600, till the climax is reached on April 27th with 29,825. During May the numbers are low, 1,045 to 6,505, in June they rise somewhat, 13,610 on the 11th and 15,450 on the 27th, falling again in July to numbers between 2,895 and 7,930. August shows a series of rises with falls between, the tops being 18,200 on the 10th, 19,400 on the 14th, 14,700 on the 15th, 16,915 on the 24th, and 10,970 on the 29th. September begins at a low level, reaches 11,942 on the 4th, and, with falls between, 27,177 on the 12th, 13,440 on the 20th and 27,312 on the 20th, followed by 10,582 on 21st, 18,450 on 23rd, 11,850 on 24th, and 12,110 on 30th. October is also high, with 16,973 on the 9th, 27,790 on 14th, and 24,480 on 24th. November shows one high figure, 10,937 on the 8th; while December ranges from 1,724 to 2,755, the year's record ending very much at the same level at which it commenced in January.

The range in number of the Copepoda per net, 30 to 29,800, is considerable compared with that of some other groups.

The monthly averages of the Copepoda per net during this year are as follows:—

| | | | |
|---|---|---|---|
| Jan. ... ... | 1,816 | July ... ... | 5,462 |
| Feb. ... ... | 793 | Aug. ... ... | 5,496 |
| Mar. ... ... | 1,379 | Sep. ... ... | 6,514 |
| Apr. ... ... | 5,858 | Oct. ... ... | 17,572 |
| May ... ... | 3,415 | Nov. ... ... | 6,923 |
| June ... ... | 12,138 | Dec. ... | 2,289 |

The highest averages here (June and October) do not quite coincide with the maxima (April and September-October) in the previous treatment where the days were taken singly. The explanation is, of course, that although April contains a maximum far above that of June, it also contains in the earlier part of the month many low records that pull down the average when the month is treated as a whole. The maxima in high average bulk of catch extending over the month, but not in exceptional catches, are seen from this list to be in June and October, and especially in the latter, which agrees well with the curve on p. 182.

If we look now for the largest individual hauls of a single species of Copepod we find that they occur in April, August and September. The following are some of the more important of these:—

| | | |
|---|---|---|
| April | 9—Pseudocalanus elongatus | 16,000 |
| | 9—Temora longicornis | 19,000 |
| | 17— „ „ | 6,000 |
| | 22— „ „ | 6,500 |
| | 22—Acartia clausi | 4,500 |
| | 22—Calanus helgolandicus | 4,600 |
| | 23—Acartia clausi | 8,000 |
| | 23—Calanus helgolandicus | 13,480 |
| | 24— „ „ | 9,240 |
| | 24—Acartia clausi | 28,000 |
| | 26—Pseudocalanus elongatus | 8,700 |
| Aug. | 10—Oithona similis | 9,000 |
| | 13— „ „ | 14,000 |
| | 17— „ „ | 25,000 |
| | 24—Acartia clausi | 23,000 |
| | 24— „ „ | 29,000 |
| | 24—Oithona similis | 21,000 |
| | 26—Acartia clausi | 16,500 |
| | 27— „ „ | 24,700 |
| | 29—Pseudocalanus elongatus | 23,000 |
| Sept. | 4—Acartia clausi | 23,600 |
| | 4—Pseudocalanus elongatus | 36,000 |
| | 11— „ „ | 21,000 |
| | 12— „ „ | 33,600 |
| | 18— „ „ | 25,000 |
| | 20—Oithona similis | 29,270 |

These also bear out the idea of maxima in April and in autumn, the latter being the more important one.

We shall now discuss the occurrence of some of the more important species of Copepoda separately.

### Calanus and Anomalocera.

The two large Copepoda, *Calanus helgolandicus* (Claus.) and *Anomalocera pattersoni*, Temp., are both regarded as oceanic species, and are both present in fair abundance in the Irish Sea. They are two of the most conspicuous objects in our plankton gatherings, and can readily be picked out with the eye and counted.

*Calanus* was present in our gatherings in 1907 during every month of the year from January 8th to December 30th. It was represented on nearly every occasion when hauls were taken, and in some cases when absent from one net it was taken in another gathering made on the same day, showing that the apparent absence was due to some imperfection in the sampling of the sea. When, then, we find that a species like this is not recorded from a particular haul at a time of year when gatherings are being taken once a week only, one is inclined to suspect from the appearance of the records at other times when the observations were more frequent, that if another haul had been taken that day or on an adjoining day the species would have been represented. The numbers as a rule are not large. They are low at the beginning of the year, and rapidly increase during April. We quote a few of what seem to us representative catches from each month. They are all from the surface nets when not otherwise stated:—

| | Surface Nets. | | 0-10 faths. | Shear net. |
|---|---|---|---|---|
| Jan. 8 ..... | 14 | — | — | — |
| Feb. 26 ..... | 3 | — | — | — |
| Mar. 26 ..... | 2 | — | — | — |
| April 1 ..... | 20 | 45 | 400 | — |
| 2 ..... | 330 | 150 | 6 | — |
| 11 ..... | 100 | 260 | 220 | — |
| 13 ..... | 135 | 150 | 360 | — |
| 16 ..... | 20 | 75 | 2,000 | — |

| | Surface Nets. | | 0-10 faths. | Shear Net. |
|---|---|---|---|---|
| 18 ..... | 1,600 | 600 | 1,200 | — |
| 22 ..... | 600 | 600 | 1,000 | 4,600 |
| 23 ..... | 1,500 | 1,250 | — | 4,000 |
| 23 ..... | 1,600 | 2,500 | 1,700 | — |
| 23 ..... | 600 | 650 | — | 13,480 |
| 23 ..... | 360 | 380 | — | 9,240 |
| 24 ..... | 3,300 | 2,000 | 1,100 | — |

This is the climax; during May, June and July the numbers are lower.

| | | | | |
|---|---|---|---|---|
| July 31 ..... | 1,570 | — | — | — |
| Aug. 9 ..... | 600 | — | — | — |
| 10 ..... | 2,500 | — | — | — |
| 21 ..... | 100 | 200 | 125 | 3,260 |
| 21 ..... | 2 | 2 | 40 | 140 |

During most of August and September the numbers keep low, although in former years we have, on occasions, taken very large hauls of *Calanus* in Port Erin bay in August and September.

| | | | | |
|---|---|---|---|---|
| Sept. 11 ..... | 35 | 40 | 675 | — |
| 12 ..... | 5 | 11 | 300 | 2,600 |
| 18 ..... | 1 | 1 | 255 | — |
| 19 ..... | 32 | 15 | 440 | 4,920 |

Then the surface hauls ran as follows:—September 24th, 500; September 30th, 20; October 9th, 200; October 14th, 2,700; October 24th, 475; November 4th, 30; November 8th, 85; November 16th, 8; November 25th, 12; December 12th, 2; December 20th, 0; December 23rd, 21; December 30th, 2. And so the year ended as it began, with low numbers, the highest figures being in April, and then again in Autumn; but the species is never absent.

It will be noticed that during April the larger numbers are sometimes in the surface nets and sometimes deeper; but that in September the weighted net at 10 fathoms contains most. The shear-net is not comparable with the others.

In the latter half of July, the "Ladybird" made a run up the west coast of Scotland, to Skye, and took a few

vertical plankton hauls in deep water. At the entrance to Loch Fyne, off Skate Island, in 104 fathoms, we got 13,000 adult *Calanus helgolandicus* in one haul on July 18th; and off Buidhe Island, near East Loch Tarbert, in 76 fathoms, we got 10,000 of the same species on July 27th, along with *Euchaeta norvegica*, *Nyctiphanes norvegica*, and other interesting forms. *Calanus* seems to be permanently present in the deep water of the west coast.

*Anomalocera*, on the other hand, first appears in our records on March 29th, and then only in the form of metanauplii (100, 170, and 30 in surface hauls off the Calf Island). Then on April 1st the deep net (10 fathoms) took 75 young, in their second-last stage of development. The same young stages were taken again on April 4th, 5th and 6th, with various nets, chiefly on the surface, and the first adults on April 9th, after which both adults and young continued to occur during the remainder of the month. The numbers on a few dates in April are:—

| | | Surface Nets. | | 10 faths. | | |
|---|---|---|---|---|---|---|
| Adults | April 9 | 150 | 80 | 20 | Station II. | |
| Young | 9 | 200 | 100 | 10 | ,, | |
| ,, | 10 | 170 | 500 | 20 | Station I. | |
| ,, | 10 | 500 | 750 | 400 | Station II. | |
| Adults | 16 | 80 | 160 | 10 | Station V. | |
| Young | 16 | 160 | 400 | 60 | ,, | |
| Adults | 23 | 100 | 50 | 75 | Station I. | |
| Young | 23 | 200 | 150 | 0 | ,, | |
| Adults | 24 | 100 | 75 | 50 | ,, | |
| Young | 24 | 100 | 75 | 0 | ,, | |
| Adults | 26 | 9 | 10 | 37 | ,, | Shear, 500 |
| Young | 26 | 40 | 20 | 20 | ,, | |

*Anomalocera* does not occur in our records during May, June and July, but it must be remembered that during these months gatherings were only taken once a week. The species is recorded again on August 19th, and continues to be represented, in small numbers, by both adults and young, throughout August and September; and finally on November 8th. We have, however, noted its

occurrence in previous years in the open sea in January and February (Lanc. Sea Fisheries Laby. Report, No. XIV, 1905, p. 35); and Mr. I. C. Thompson recorded an immense shoal between Douglas and Port Erin in May, 1888 (Proc. L. Biol. S., Vol. III, p. 183).

### Pseudocalanus.

It has seemed advisable to take out separately the distribution of the Copepod *Pseudocalanus elongatus*, which is present and fairly abundant throughout the year. It is represented in almost every gathering, and by high numbers (for a Copepod) in nearly every month. The greatest quantity for a single net rises in April to over 8,000 more than once, and in August reaches 16,000. But the maximum is seen from August 29th to September 18th, when the following very high numbers occur, with occasional lower ones between them:—23,000, 36,000, 21,000, 33,600, 15,000, 12,000, 11,000, 25,000, 12,800—each of these being the catch in a single net. These are, of course, the picked highest numbers of the year, and they all happen to represent hauls of the weighted open tow-net, which indicates that this species of Copepod is in greatest abundance a few fathoms below the surface. Quite apart from the exceptional hauls quoted above, we find that neither the surface nets nor the closing vertical nets worked in deeper zones caught nearly so many of this species as the weighted net ranging down to about ten fathoms. From the frequency with which similar nets and adjacent hauls give widely differing results, we are inclined to regard this as a species which is distributed irregularly in swarms, or patches of greater density.

### Microcalanus.

The distribution of *Microcalanus pusillus*, G. O. Sars, in our district throughout the year is interesting. It

appears for the first time in our records late in August, and remains fairly constantly present but never very abundant throughout the autumn and winter until January, when it disappears. During the first few weeks it is only in the offshore hauls, appearing first out in mid-channel on August 24th in the Hensen and Nansen nets that were let down to 60 fathoms and hauled up vertically. As specimens were present in all the nets that were closed when they had been pulled up to 45 fathoms and were not present in the surface and other nets used above that level, it is evident that this Copepod was on its first appearance only in the deep water in mid-channel. It was encountered next on August 26th, in the weighted net hauled at 10 fathoms, on the inner edge of the Train Bank, some eight miles off land. On August 31st it made its appearance at Station I in the Hensen and Nansen nets hauled up from 24 fathoms, and in the weighted net from 10 fathoms—the latter having 350 specimens. It was also present on September 2nd and 3rd, under the same circumstances. On September 4th we again found it in mid-channel in the vertical nets which had been down to 60 fathoms; it was still not present in the surface nets nor in the inshore waters.

On September 6th, *Microcalanus* appeared for the first time inshore, at Station IV, off the Calf Island, but only in the Hensen and Nansen nets which had been closed at 8 and 15 fathoms respectively; it was not present in the surface hauls taken at the same time. It was next met with on September 11th, at Station V, south of the Calf Sound, inside the Wart Bank, when 100 specimens were taken in each of the two surface nets, 150 in the weighted net at 10 fathoms, and 5, 5, 5, 3, in the four vertical nets (2 Hensen and 2 Nansen) hauled from 20 up to 10 fathoms. It had evidently become

distributed by this time all through the water around the Calf Island. The following day, the species was present in nearly all the numerous nets worked at various depths down to 60 fathoms in mid-channel; and it then reached its climax in numbers, 2,000 in the net at 10 fathoms and 2,500 in an open tow-net attached to the shear-net at 20 fathoms. For some days after this *Microcalanus* was not taken in any of the nets, and then on September 21st it turned up for the first time in the surface gatherings taken across Port Erin Bay. It was present in these bay gatherings on October 1st (35) and 24th (100), November 8th (100), December 20th (80) and 23rd (50), and finally January 8th (50 specimens).

This record looks like the immigration of an oceanic species up the deep water of the mid-channel between the Isle of Man and Ireland, and then its gradual spread in late autumn into the shallower inshore waters and finally to the surface of the bay, where it remained throughout the winter.

### Centropages and Temora.

In the Blue-book (Cd. 3837, 1907, p. 175) on the International Fishery Investigations in the Southern Area during 1904-5, issued under the direction of the Marine Biological Association, the statement is made in regard to *Centropages hamatus* (Lilljeb.) that "in the Irish Sea it is a seasonal species occurring only in the summer."

We have no hesitation in saying, on the contrary, that this Copepod occurs in the Irish Sea all the year round. It is on our records for 1907 in every month, and is practically continuously present from January 8th to December 30th. The numbers are low at the beginning of the year, but reach 600 in one haul of the surface net by April 9th, and 1,300 on April 24th. Contrary to the

usual rule, this species seems more abundant on the surface than deeper—e.g.,

| | Surface nets. | | 10 faths. | |
|---|---|---|---|---|
| April 18..... | 100 | 100 | 0 | Station II. |
| 19..... | 400 | 230 | 25 | Station I. |
| 19..... | 190 | 112 | 50 | Station II. |
| 22..... | 150 | 50 | 50 | Station I. |
| 23..... | 100 | 50 | 0 | Station IV. |
| 24..... | 1,300 | 800 | 75 | Station I. |
| 24..... | 700 | 1,140 | 75 | Station II. |

These last two hauls show the highest numbers recorded for the year; they fall to 100 or under during May, June and July, recover to 600 by August 12th, drop again to the tens, or a hundred or two at most, later in August—when the larger numbers are sometimes in the deeper nets, e.g.—

| | Surface nets. | | 10 faths. | |
|---|---|---|---|---|
| August 24 ..... | 40 | 20 | 225 | Mid-Channel |
| 24 ..... | 30 | 50 | 700 | " |
| 27 ..... | 30 | 20 | 100 | Train Bank |

During September, while the surface hauls remain relatively small the deeper nets occasionally get larger numbers, such as 420, 130, 230. On September 16th, however, at Station I, the numbers were:—surface nets, 255 and 47; weighted net (10 fathoms), 100. On September 19th a surface haul just outside the bay gave 240, and the following day successive surface hauls at Station I gave 165, 230, 165, 140. On September 23rd the record was 300, on 28th 100, in October 100, 150, 25, and in November and December the numbers drop to units. How a species with this record can be called "a seasonal species occurring only in the summer" is difficult to understand. The mistake can only be attributed to the attempt to draw conclusions from insufficient observations: twenty-three samples in the year is quite an inadequate treatment of the Irish Sea. There are various other statements in the Blue-book in

regard to the distribution of species in the Irish Sea which are contrary to our evidence; but it is impossible to go into all these cases now. Let us take *Temora longicornis* (Müller) as a final instance. As the result of the international observations, it is stated that "in the Irish Sea, it can be said to be a summer form"; while the fact is that on our records it occurs the whole year round from January to December, attains to high numbers in early spring, and remains fairly abundant into late autumn. It reaches close on 7,000 in one haul on April 1st, and 19,000* on April 9th; and shows 1,280 and 1,600 up to the 23rd of September.

*Temora longicornis* seems to be equally abundant inside the bay and in the open sea, on the surface and in the deeper waters. Sometimes the large numbers are in the surface nets and at other times in the weighted net from below. This is one of the species that congregates in swarms, and so is occasionally caught in unusually large numbers. Of four similar hauls taken across Port Erin Bay on April 13th, the first two gave 875 and 620 and the last two 1,550 and 3,700 specimens of *Temora*. On the same date three hauls (two surface and one deeper) taken outside (Station III) gave 800, 850 and 900 specimens, which indicates an even distribution, but half an hour later a couple of miles away the same two surface nets gave 2,400 and 4,750 specimens; and moreover in this last case nearly all the *Temora* in the 2,400 were young, while in the second net the 4,750 were all adults, indicating a segregation of the stages in swarms. Many other examples of both agreement and divergence between the comparable nets could be given, and some may be seen in the Forms we have printed in this Report.

The records of some of the other species of Copepoda

* These numbers quoted are, of course, the highest records.

on our Forms will probably well repay analysis, but these must now be left over for another occasion.

### Cladocera.

The two species of this group found in our district, *Podon intermedium* and *Evadne nordmanni*, occur mainly in summer, in a wide sense, ranging from the end of March to the beginning of October. Our first record of *Podon* is six specimens on March 26th, and the last is fifty on October 9th. *Evadne* begins with ten on March 29th, reaches 500 on April 9th, and ends with 50 on September 20th. Tens, twenties and thirties are common numbers in the records of both species, but sometimes the hundreds are reached. As a rule there is no great difference between surface and deeper hauls, and occasionally there is great constancy of results, indicating an even distribution:—e.g., on April 18th at Station II.

| At Station II. | Surface nets. | | 10 faths. | Shear. | |
|---|---|---|---|---|---|
| Podon intermedium ..... | 150 | 150 | — | — | |
| Evadne nordmanni ..... | 100 | 100 | 150 | 50 | 50 |

On April 19th, in the bay, two similar surface hauls took 40 and 37 *Podon*, and 75 *Evadne* each; and at the same time, at Station II, ten miles off, the two surface nets took 40 *Podon* and 75 *Evadne* each. Other similar cases might be quoted; but on the other hand there are diverse hauls on other dates showing a very uneven distribution. The numbers during May and June are relatively high:—

| | | | | | | |
|---|---|---|---|---|---|---|
| Podon ..... | 190 | 80 | 150 | 100 | 100 | 150 |
| Evadne ..... | 60 | 80 | 300 | 300 | 300 | 650 |

This is the highest point reached by *Evadne*, and this form is practically absent, or only occasionally present, during the latter half of August and parts of September. *Podon* reaches a climax (500) rather later, on August

13th, and soon after that drops to tens and even units, with an occasional appearance (August 31st, 200) in greater numbers. During most of September the group is but scantily represented; although neither species is ever absent for long, and occasional larger numbers occur —such as September 19th, off Calf Island, deep net, *Podon* 70, and *Evadne* 100; and September 20th, Station I, shear net, *Podon* 110 and 290, deep net 140; and, at the same time, inside the bay, 182. On September 23rd the ordinary surface net inside the bay took 550 *Podon*, and the following day 100, after which the numbers fall off rapidly.

### Tomopteris.

This pelagic worm occurs in our records occasionally throughout April, and then again in August, September, and onwards till the end of the year. It is not represented on our Forms during January, February, March, May, June and July; but these are the months when only weekly gatherings were made, and the question arises whether, if as many hauls had been taken then as in April and August, *Tomopteris* might not have been found.

Our first record of *Tomopteris onisciformis*, Esch., in 1907, is one specimen at Station II, in the weighted net (10 fathoms), on April 1st. It is never very abundant, being usually taken in ones and twos, and generally in the deeper nets—the vertical, the weighted, or the shear. This last net caught the largest numbers: it had 10 specimens on April 26th, 85 on September 19th, 95 and 65 on September 20th. The ordinary surface net inside the bay got 25 on August 15th, and 6 the following day, and the weighted net had 14 on September 19th and 12 on September 20th. From that time onwards to the end of

the year the numbers are under 10 at a time, generally one or two only.

From the records in the Blue-book (Cd. 3837, pp. 233, 241) it seems that this oceanic form occurs comparatively rarely at Plymouth and elsewhere in the English Channel—at Plymouth on three dates in 1904, and on two only in 1905. Unfortunately no numbers are given in the Blue-book, so no exact comparison can be made; but the probability is that—looking at our records of frequent occurrence over six months and of hauls extending up to 85 and 95 in a net—the species is very much more abundant in the Irish Sea than in the English Channel—why, then, is the Irish Sea described as the more "neritic" of the two?

### Oikopleura.

The common species of *Oikopleura* that occurs in our district (*O. dioica*) is also a form which deserves special notice. It occurs throughout the year, being present in every month, and represented in nearly every gathering. It is absent or rare in the case of the hauls taken on a few dates between August 24th and 28th, and then again on September 4th and 5th. With those exceptions, *Oikopleura* is one of the most constant of organisms at all times of the year, and, moreover, is usually present in quantities that range within narrow limits, so that it does not vary to the extent that some Copepoda and Diatoms do. In the winter months—December, January, February and March—the numbers taken are low, but from April to November inclusive quantities of a thousand or two per net are very frequently taken. The highest numbers occur in April, and they only reach 5,500 per net, so there is no marked maximum.

In some cases the numbers of *Oikopleura* remain

remarkably constant for several hauls, indicating a very general distribution through the water. For example, in one traverse of Port Erin Bay 2,780 were caught, and in the return traverse 2,030; then again, two adjacent hauls gave 3,840 and 3,600 respectively, and another pair of simultaneous hauls gave 2,250 each. But on the other hand, on another occasion, two successive traverses of the bay gave 5,050 and 2,480 respectively, and other examples of diverse results might be quoted from our records. But on the whole the impression received by an inspection of the Forms is that *Oikopleura* is more evenly distributed through the water than most of the other common organisms.

## COMPARISON OF PORT ERIN BAY WITH THE OPEN SEA.

We have 136 surface hauls taken across Port Erin Bay throughout the year, from January 8th to December 30th. All months are represented, and nearly all weeks. January is the only month in which less than three weekly hauls were taken, and in all the remaining months except February, May and June there are at least four weeks represented. During April, August and September the observations were almost daily. In the open sea, however, surface hauls were only taken when the yacht was at work in parts of March, April, August and September. Mr. Douglas Laurie, who has kindly helped us by preparing some of the curves showing distribution, has made a comparison for April between the hauls taken (by himself with the assistance of others) and those that were being taken at the same time with similar surface nets from the yacht at the outside stations. The hauls from the yacht lasted 15 minutes each. Those taken in the bay consisted of a double traverse which occupied on

the average 20 minutes. Consequently the numbers recorded for the latter series have been decreased by one-fourth each, after which correction we consider that they are fairly comparable with the others.

We give here (fig. 8) an unsmoothed curve for the total plankton in the bay throughout the year, which shows well the great spring maximum in April and lesser elevations in June, August and October. When compared with the list of quantities given above for the

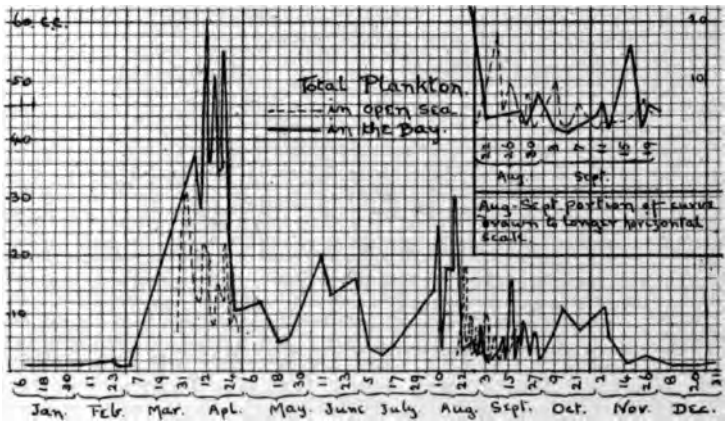
Total Plankton.
---- in open sea.
—— in the Bay.
Aug.
Sept.
Aug. Sept. portion of curve drawn to larger horizontal scale.
Jan. Feb. Mar. Apl. May. June July Aug. Sept. Oct. Nov. Dec.

FIG. 8.

total plankton collected daily, or with the curve shown in dotted lines here (fig. 8) for the plankton of the open sea taken by itself in spring and in autumn, it will be noticed that the differences are not very great. The spring maximum is rather earlier in the open sea, and does not rise to such exceptional heights per net. In autumn (August and September) on the other hand the maximum for the open sea is, so far as our evidence shows, rather later than that for the bay, and again it does not rise to such heights. It is possible, however, that the total hauls in the open sea, per net, are kept

unduly low by the vertical nets being averaged along with surface and other quarter-hour horizontal ones. Occasionally the vertical nets (especially the Nansen) obtained very large catches, but over the whole they may have depressed the sea-average.

The great majority of the hauls in the bay were taken along a line crossing from S. to N. starting at the Life-boat slip and ending at Spaldrick Creek, and this was known as line I.; while a second traverse, line II, only occasionally made, was further out at the mouth of the bay, opposite the ruined breakwater.

Looking at the records for line I during April, when the hauls were most frequent, we find on the whole a decrease in Diatoms as the month goes on, associated with a rise in Copepoda. As a general rule we find that hauls rich in Diatoms tend to be poor in Copepoda, and *vice versâ*; and our records show that the change may take place even within the hours of a day in the shallow water of the bay. For example, consider Form **25**, on April 13th, when the first pair (*a*) of hauls (A going North and B returning South) was taken (by Mr. Laurie) in the afternoon, while the second pair (*b*) was taken (by Professor Herdman) a few hours later in the early evening. Although *a* is a smaller haul than *b*, it contains more than three times as many Diatoms and nearly three times as many Copepod Nauplii and later larval stages, but less than half as many adult Copepoda. There had evidently, then, been a sudden decrease in the number of Diatoms (chiefly *Chaetoceros contortum*), and a certain amount of increase in the adult Copepods, and also in Sagitta, Crab Zoëas, and Gasteropod larvae.

On the other hand, we have an exception to the general rule that Diatoms and Copepoda do not abound together, on April 17th, when, compared with April 16th,

## 25.—Port Erin Bay, April 13th.

| Net used | I.A | I.B | I.A | I.B |
|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 0 | 0 |
| Catch in c.cm. | 26 | 24 | 26·5 | 45·5 |
| | *a* | | *b* | |
| Biddulphia mobiliensis | 10,000 | 6,000 | 2,500 | 3,000 |
| Chaetoceros contortum | 82,000 | 33,000 | 500 | 9,000 |
| ,, decipiens | 2,000 | 3,000 | — | 1,000 |
| Coscinodiscus concinnus | 5,000 | 5,000 | 6,500 | 3,500 |
| Rhizosolenia semispina | 4,000 | 1,000 | — | 500 |
| Thalassiosira nordenskioldii | 5,000 | — | — | — |
| ,, subtilis | 12,000 | 6,000 | 1,500 | 24,000 |
| Lauderia borealis | 5,000 | 1,000 | — | 500 |
| Ceratium fusus | — | 2,000 | — | 350 |
| ,, tripos | 3,000 | — | — | — |
| Pleurobrachia pileus | — | — | 3 | — |
| Medusoid gonophores | 70 | 30 | — | 100 |
| Sagitta bipunctata | 3 | 4 | 14 | 10 |
| Larval Polychaeta | 1,000 | 500 | 2,000 | 650 |
| "Mitraria" | 500 | — | 100 | 300 |
| Crab zoea | — | — | — | 20 |
| Mysis stage of Crangon | 30 | 15 | 100 | 150 |
| Other larval Decapods | 100 | 100 | — | — |
| Podon intermedium | 25 | 15 | 100 | — |
| Evadne nordmanni | 25 | 15 | 300 | — |
| Calanus helgolandicus | 200 | 75 | 300 | 350 |
| Pseudocalanus elongatus | 1,500 | 1,500 | 3,700 | 2,150 |
| Temora longicornis | 875 | 620 | 3,700 | 1,550 |
| Centropages hamatus | — | 25 | — | — |
| Acartia clausi | 400 | — | 800 | 1,050 |
| Oithona similis | 675 | 475 | 1,000 | 300 |
| Paracalanus parvus | 175 | 130 | — | — |
| Copepod nauplii | 21,000 | 9,000 | 4,000 | 7,000 |
| ,, juv. | 23,000 | 11,000 | 5,500 | 18,000 |
| Barnacle nauplii | 3,500 | 2,750 | 4,300 | 6,000 |
| ,, cypris stage | 40 | 30 | 200 | 300 |
| Gasteropods, larval | — | — | 1,000 | 500 |
| Oikopleura sp | 1,500 | 1,800 | 2,500 | 3,000 |
| Fish eggs— | | | | |
| Rockling | — | 2 | — | 2 |
| Green Cod | 1 | — | — | — |
| Bib | 2 | — | 1 | — |
| Spotted Dragonet | — | — | 1 | — |
| Topknot | | 3 | 1 | 1 |
| Sprat | — | — | 2 | 7 |
| Young fishes— | | | | |
| Gadoid | — | — | 1 | 1 |
| Cottus | — | — | — | 1 |

**32, 36.**—Port Erin Bay, April 16th. April 17th.

| Net used | I.A | I.B | I.A | I.B |
|---|---|---|---|---|
| Depth in fathoms | 0 | 0 | 0 | 0 |
| Catch in c.cm. | 20 | 16 | 26 | 25 |
| Biddulphia mobiliensis | 36,000 | 40,000 | 57,000 | 85,000 |
| Chaetoceros contortum | 3,000 | 1,000 | 8,000 | 6,000 |
| ,, decipiens | — | — | 5,000 | 5,000 |
| Coscinodiscus concinnus | 17,000 | 23,000 | 22,000 | 20,000 |
| Rhizosolenia semispina | 500 | — | 1,000 | — |
| ,, shrubsolei | — | — | 2,000 | — |
| Thalassiosira nordenskioldii | 1,000 | 1,000 | 2,000 | 2,000 |
| Lauderia borealis | — | — | — | 500 |
| Ceratium fusus | — | 500 | 500 | — |
| ,, tripos | — | 1,000 | — | 3,000 |
| Peridinium sp. | 1,500 | 2,000 | — | 1,000 |
| Medusoid gonophores | 3 | 3 | 64 | 92 |
| Sagitta bipunctata | 10 | 10 | 30 | 15 |
| Larval Polychaeta | 300 | 300 | 2,100 | 920 |
| "Mitraria" | — | — | 500 | — |
| Crab zoea | 2 | 5 | 1 | 1 |
| Mysis stage of Crangon | — | — | 2 | 2 |
| Nephrops, 1st stage | — | — | 1 | 1 |
| Calanus helgolandicus | 150 | 50 | 240 | 130 |
| Pseudocalanus elongatus | 800 | 350 | 1,800 | 980 |
| Temora longicornis | 4,600 | 2,800 | 6,000 | 4,400 |
| Centropages hamatus | 100 | 50 | 16 | 8 |
| Acartia clausi | 1,250 | 800 | 625 | 720 |
| Oithona similis | 250 | 100 | 210 | 530 |
| Anomalocera juv. | 50 | 50 | — | — |
| Copepod nauplii | 6,000 | 11,500 | 40,000 | 25,000 |
| ,, juv. | 10,000 | 12,000 | 15,000 | 16,000 |
| Barnacle nauplii | 1,000 | 350 | 2,100 | 920 |
| ,, cypris stage | 200 | 200 | 80 | 80 |
| Oikopleura sp. | 2,250 | 2,250 | 2,850 | 2,400 |
| Fish eggs— | | | | |
| Rockling | — | 4 | — | — |
| Common Dragonet | 2 | 3 | 1 | — |
| Bib | 1 | 2 | — | 1 |
| Topknot | 1 | 3 | — | — |
| Sprat | — | 1 | — | 2 |
| Dab | — | — | — | 1 |
| Young fishes— | | | | |
| Clupeoid | 2 | — | — | 1 |
| Gadoid | — | — | 1 | 2 |

both Diatoms and Copepoda had increased considerably (see Forms **32, 36**).

Copepod Nauplii, however, seem to rise and fall in number on the same dates as the Diatoms; but on the

whole the Copepod Nauplii increase to a maximum on April 17th, when they are exceptionally numerous (see Form **36**), and then fall off, so that the numbers at the end of the month are much the same as those at the beginning of the period under observation.

It is clear then that the problem of the periodic distribution of these various organisms is not quite so simple as might have been expected. There are probably three distinct factors at work:—(1) the periodicity of the stages in the normal life-history of the organism; (2) irregularities introduced by the inter-action of the

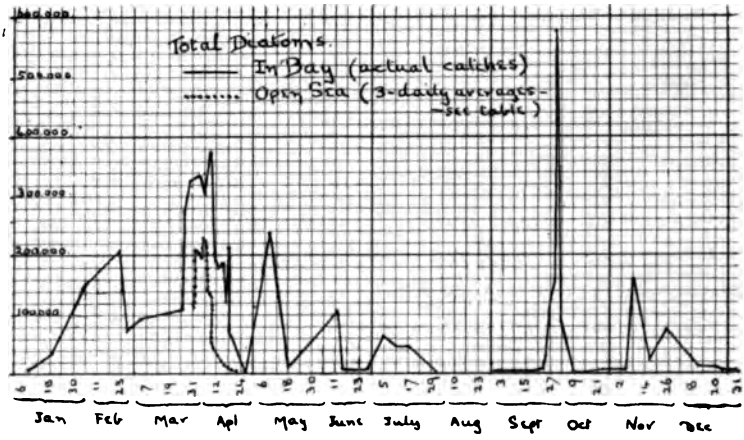


FIG. 9.

organisms, as when one group serves as food, or enemy of another; and (3) abnormalities as to either time or abundance caused by weather conditions, which may either prevent the normal or permit of an abnormal development of certain species.

Mr. Laurie has kindly drawn for us the accompanying curve (fig. 9) representing our results as to the Diatoms in the bay compared with those from the open sea.

It will be noted that the general character of the curves is similar, though the catch in the bay is consistently greater than that at sea. The less sudden diminution in the number of Diatoms in the bay from April 10th to April 17th will be observed, and the sudden drop which then follows, bringing the curves close together by the 23rd of the month.

The numbers of the total Diatoms from the hauls in the open sea during a month in spring are as follows:—

| Date. | Hauls. | Average per haul. | 3-day average.* |
|---|---|---|---|
| Mar. 29 | 4 | 45,162 | — |
| April 1 | 3 | 103,333 | 111,998 |
| 2 | 2 | 187,500 | 209,055 |
| 4 | 4 | 336,333 | 198,722 |
| 5 | 2 | 72,333 | 230,111 |
| 8 | 3 | 281,667 | 142,133 |
| 9 | 5 | 72,400 | 136,133 |
| 10 | 6 | 54,333 | 56,578 |
| 11 | 4 | 43,000 | 44,175 |
| 13 | 6 | 35,192 | 32,811 |
| 15 | 4 | 20,240 | 23,465 |
| 16 | 8 | 14,962 | 16,651 |
| 18 | 4 | 14,750 | 13,237 |
| 19 | 4 | 10,000 | 8,349 |
| 22 | 4 | 297 | 3,746 |
| 23 | 6 | 942 | 551 |
| 24 | 4 | 415 | 661 |
| 25 | 6 | 625 | 1,780 |
| 26 | 4 | 4,300 | 3,880 |
| 27 | 7 | 6,714 | — |

* By "three-day averages" is meant taking always the average of the three adjacent days upon which catches were made, *i.e.*, the average of the 1st, 2nd and 3rd, then of the 2nd, 3rd and 4th, then of the 3rd, 4th and 5th; and so on.

### Bay Diatoms throughout the Year.

A general inspection of the unsmoothed curve shows a well-marked maximum at the end of March and earlier part of April. The marked increase of Diatoms, and also of Copepod nauplii, towards the end of March is seen well in the surface hauls taken in Port Erin Bay on the following three dates:—

| | March 26. | | March 27. | | March 29. |
|---|---|---|---|---|---|
| | 12 c.c. | | 14·5 c.c. | | 18·5 c.c. |
| Total Diatoms = | 220,000 | ... | 277,000 | ... | 326,000 |
| Biddulphia mobiliensis..... | 46,000 | ... | 50,000 | ... | 58,000 |
| Chaetoceros debile ..... | 6,000 | ... | 8,000 | ... | 10,000 |
| ,, decipiens ..... | 100,000 | ... | 150,000 | ... | 160,000 |
| Coscinodiscus concinnus ..... | 64,000 | ... | 67,000 | ... | 75,000 |
| Copepod nauplii ..... | 7,000 | ... | 27,000 | ... | 35,000 |

We have only quoted those species of Diatoms which are present in greatest abundance and which make up the bulk of the catch. All are included in the totals given. There is also an autumn maximum showing a very high peak at the end of September. Omitting, however, the single catch of September 30th (which is due in the main to *Rhizosolenia semispina*) the peak is reduced to less than one-third its former height. A remarkable feature of this September hump is the sudden character of its appearance and disappearance and its short duration (six days). An inspection of the temperature curve of the year for the water of the bay (fig. 10) shows that the sudden increase

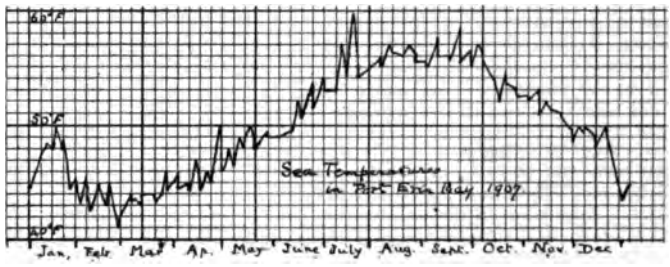


FIG. 10.

in the phytoplankton coincided with the maximum in temperature, and our weekly weather records at the Biological Station show at that same time a week of fine calm weather with easterly breezes (S.E. and E.S.E.). We have noticed the same phenomenon in previous years, both at Port Erin and on the west coast of Scotland, which seems to indicate that if weather conditions be suitable at

**122, 123.**—Port Erin Bay, October 1st and 14th, November 8th. Surface.

| | Oct. 1 | Oct. 14 | Nov. 8 |
|---|---|---|---|
| Depth in fathoms | 0 | 0 | 0 |
| Catch in c.cm. | 1·5 | 11·5 | 6 |
| Biddulphia mobiliensis | 500 | — | 5,600 |
| Chaetoceros contortum | 2,750 | — | 300 |
| „ debile | 500 | — | — |
| „ decipiens | 3,500 | — | 3,000 |
| „ sociale | 3,250 | — | 400 |
| „ teres | 2,000 | — | 146,000 |
| „ densum | 3,250 | — | 400 |
| „ boreale | 750 | — | — |
| „ subtile | 250 | — | — |
| „ diversum | 750 | — | — |
| Coscinodiscus concinnus | — | — | 1,800 |
| Rhizosolenia semispina | 68,300 | — | 400 |
| „ alata | 1,000 | — | — |
| „ shrubsolei | 2,500 | — | — |
| Coscinodiscus radiatus | 500 | — | 1,000 |
| Bacteriastrum sp. | 250 | — | — |
| Guinardia flaccida | 1,000 | — | 300 |
| Streptotheca sp. | — | — | 100 |
| Ceratium tripos | — | — | 200 |
| Medusoid gonophores | 2 | 3 | 20 |
| Sagitta bipunctata | 5 | 190 | 56 |
| Tomopteris onisciformis | — | 8 | 1 |
| Larval Polychaeta | — | 250 | — |
| "Mitraria" | — | 250 | 100 |
| Crab zoea | — | 10 | — |
| Mysis stage of Crangon | 1 | 20 | 1 |
| Erythrops sp. | — | — | — |
| Microniscus calani | — | 50 | — |
| Calanus helgolandicus | — | 2,700 | 85 |
| Pseudocalanus elongatus | 220 | 8,100 | 1,350 |
| Temora longicornis | — | 70 | 8 |
| Centropages hamatus | — | 150 | 2 |
| Anomalocera pattersoni | — | — | 1 |
| Acartia clausi | 275 | 650 | 1,770 |
| Oithona similis | 485 | 12,600 | 6,170 |
| Paracalanus parvus | 30 | 3,300 | 1,450 |
| Microcalanus pusillus | 35 | — | 100 |
| Parapontella brevicornis | — | 30 | — |
| Isias clavipes | — | 190 | 1 |
| Copepod nauplii | 2,500 | 5,500 | 3,200 |
| „ juv. | 500 | 23,000 | 4,500 |
| Gasteropods, larval | 250 | — | 300 |
| Lamellibranchs, larval | — | 1,250 | 300 |
| Oikopleura sp. | 50 | 725 | 575 |

the end of autumn the phytoplankton may suddenly increase so as to constitute a second maximum in the year, the first being in spring; but that this possible maximum may be so modified in time and in amount by temperature and wind as to be unrecognisable. In 1906 it was very much more marked at Port Erin (see XXth Ann. Report, p. 53) than in 1907, and extended from September 20th to the end of the month.

The phytoplankton minimum for the bay occurs in August, no Diatoms being taken from August 9th to August 23rd (see curve), though nettings were taken on all days, except three, included between these dates.

As an example of a sudden change in the plankton we may compare the surface hauls taken in the bay on October 1st and 14th (see Form **122**). The total quantities of the two gatherings were 1·5 and 11·5 respectively; on the 1st, Diatoms were relatively abundant (over 91,000); by the 14th they had disappeared. But Sagitta and various larvae, and especially Copepoda, had greatly increased in number by the latter date. The adult Copepoda in all numbered only 1,045 on the 1st, while they reached 27,790 by the 14th; younger forms and Nauplii had also become much more abundant. By November, however, the Diatoms were back in quantity, as is shown by the third column (November 8th), and Copepoda have begun to decrease again.

### Bay Copepoda throughout the Year.

Copepoda are fairly abundant in Port Erin Bay from April to November inclusive, but there are considerable ups and downs, the number per haul varying often on successive days within very wide limits.

The curve (fig. 11) shows a gradual increase from the latter part of March through April, then (with depressions

in the beginning of May and the end of August) there are successive humps in June, early August and September leading to the maximum in October. This is followed by a rapid fall in November, and the minimum extends through December, January and February, the numbers commencing to rise again in March. On comparing the two curves it will be noticed that the April maximum for Copepoda is distinctly later than that for Diatoms, and that again the October maximum for Copepoda follows after the September increase of Diatoms. To a less extent throughout the rest of the year the two curves are complementary with the exception of late August and early September, when both are low.

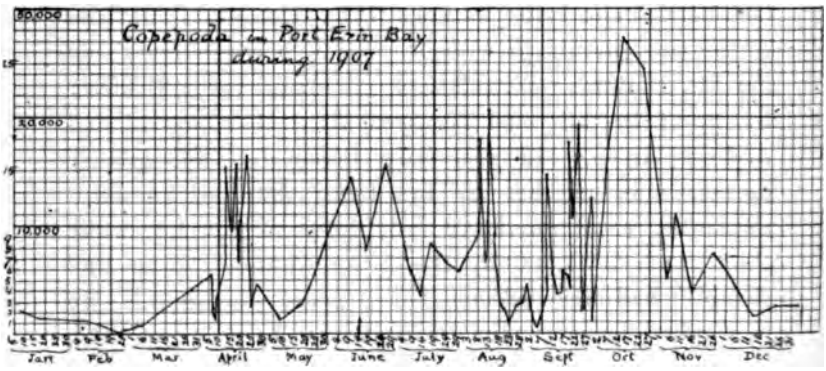


FIG. 11.

## CIRRIPEDE LARVAE IN BAY.

The Nauplius and Cypris stages of Balanus form an interesting study. The adult Balani are present in enormous abundance on the rocks of Bradda Head, and they reproduce in winter, at the beginning of the year. The Nauplii first appeared in 1907 in the bay gatherings on February 22nd, and increased with ups and downs to their maximum on April 15th, and then decreased until

their disappearance on April 26th. None were taken at any other time of the year. The "Cypris" stage follows on after the Nauplius. It is first taken in the bay on April 6th, rises to its maximum on the same day with the Nauplii, and was last caught on May 24th. Figure 12

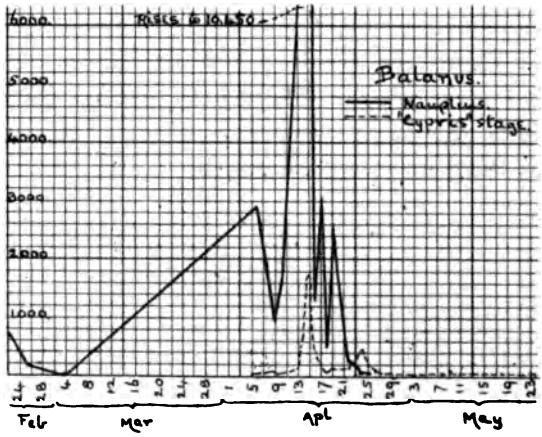


FIG. 12.

shows the curves for these two successive larval stages. It will be noticed how the "Cypris" curve keeps below that of the Nauplius, the maxima being 1,740 and 10,500 respectively. Probably the difference between the two curves represents the death-rate of the Balani during the Nauplius stage.

### SAGITTA IN BAY.

The numbers of *Sagitta bipunctata* obtained in the bay catches throughout the year run as follows per haul: —Jan., 8; Feb., 1; Mar., 1; Apr., 8, 7, 24, 15, 20, 45, 15, 7, 61, 39, 20, 5, 4; May, 6, 100, 20; June, 95, 30, 15; July, 3, 35, 40, 425; Aug., 75, 100, 1,000, 200, 600, 1,800, 800, 700, 8, 54, 65, 63, 76; Sept., 16, 10, 40, 20, 20, 3, 26, 70, 50, 100, 10, 32, 50, 10; Oct., 5, 10, 190, 90; Nov., 324, 56, 1; Dec., 1, 8, 50. Fig. 13 shows the

curve drawn from these numbers, showing the more prominent humps in the height of summer and again in October-November. *Sagitta* is present throughout the year; it is most abundant in August, and the minimum occurs in winter (January to March).

We have not yet made a curve for the occurrence of *Sagitta* outside the bay, but so far as an inspection of the numbers shows the result would not differ materially from that given above. Those nets that are comparable give much the same run of numbers. As showing, however, the difference produced by a larger net of wider

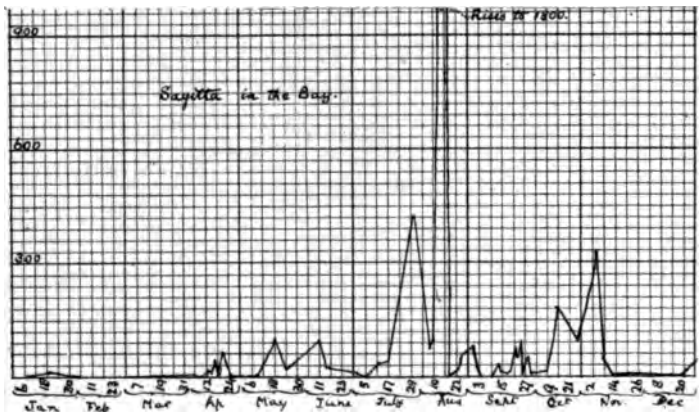


FIG. 13.

mesh, we find that during April, when the hauls with the ordinary tow-nets were giving units and tens, those taken at the same time with the shear-net ran into hundreds, as follows:—360, 123, 286, 310, 200, 200, 400, 400, 300, 800, 60. The fact, however, that the weighted tow-net, not invariably, but usually took a much larger number than the similar surface nets shows that *Sagitta* is usually more abundant in a zone of water below the surface, extending down to ten fathoms, and that consequently the

much greater numbers obtained by the shear net may be due not wholly to the size of the net and mesh but in part to the depth at which it was worked.

We give the following list as examples to show the difference in numbers of *Sagitta* caught by the surface (0 fathoms) and the weighted (10 fathoms) nets:—

| 0 faths. | 10 faths. | 0 faths. | 10 faths. | 0 faths. | 10 faths. | 0 faths. | 10 faths. | 0 faths. | 10 faths. |
|---|---|---|---|---|---|---|---|---|---|
| 6 | ... 20 | 1 | ... 30 | 1 | ... 16 | 6 | ... 22 | 2 | ... 27 |
| 1 | ... 6 | 3 | ... 11 | 4 | ... 28 | 15 | ... 85 | 24 | ...125 |
| 1 | ... 8 | 12 | ... 27 | 1 | ... 200 | 3 | ... 17 | — | ... — |
| 0 | ... 24 | 2 | ... 40 | 1 | ... 28 | 4 | ... 240 | — | ... — |
| 2 | ... 10 | 2 | ... 23 | 2 | ... 62 | 4 | ... 30 | — | ... — |

We have occasional evidence from the closing nets that *Sagitta* is even more abundant in deeper water still. For example, on April 9th, at Station II, the surface net took one specimen, the weighted net at ten fathoms took eight, and the Nansen net, which had been worked through twenty to ten fathoms, took ten. On the other hand, we have a few cases in which *Sagitta* was more abundant on the surface, e.g., on September 9th, the weighted net at ten fathoms took eight, and the two surface nets took 25 and 86 respectively. As another example of the results obtained with different nets we quote the figures from September 19th, as follows:—the surface nets took two and six, the Hensen (hauled up vertically through twenty fathoms) two, the Nansen (vertical, twenty fathoms) one, the weighted net (ranging to ten fathoms) 126, and the shear net (about ten fathoms) 1,020 specimens.

### Other Larval Forms in Bay.

Echinoderm larvae, Molluscan larvae and the Zoëa and Megalopa stages of crabs and some other larval forms are sporadic in their occurrence. They are only caught in abundance on rare occasions, and this is of course a

result simply of the reproductive phases in the life-history and has no connection with hydrographic conditions. The adults are gregarious and spawn at much the same time, the larvae hatch out in myriads at about the same time, and may then be caught in quantities. A notable example of this is the case described in the XXIst Annual Report of the Liverpool Marine Biology Committee, p. 37, of an enormous haul of Zoëas taken on April 1st, at Station III, in a very limited area—the same net hauled a couple of minutes before having caught none. Twenty-two thousand crab Zoëas were taken by the various nets on that occasion in about seven minutes.

Inside the bay the largest hauls of crab Zoëas are 200 and 300 on August 14th and 15th. They are practically absent from November to March inclusive, and during the remainder of the year occur rarely, in very small numbers.

"Mitraria" larvae are abundant in the earlier part of the year, and then again in winter—the range being from October to the end of April, with a maximum of 1,750 per haul in February. They are only occasionally found, and in small numbers, from May to September.

Polychaete larvae are more generally distributed and more abundant throughout the year. They reach a maximum in April, when the numbers per haul between April 10th and 23rd are, 260, 1,500, 2,650, 3,800, 600, 3,020, 1,330, 2,605, 700. They did not occur for some days in the middle of August, and the numbers were usually low in November, December and January, but throughout the rest of the year the general run of the figures is several hundreds per haul, occasionally reaching a thousand.

### Fish Eggs in Bay.

Floating fish eggs (containing embryos) begin to make their appearance early in April in the bay and remain low in number (mostly under ten per haul) up to the middle of the month. There is a sudden rise in the Rockling eggs on April 18th (to 43 per haul), followed by a much more marked rise on the 22nd, and the numbers remain relatively high until the 25th (reaching a maximum of 500 per haul on the 23rd), after which they fall off rapidly and remain low in number and occasional in occurrence throughout the summer and autumn until September. The other fish eggs in the bay follow much the same course as the Rockling eggs, appearing at the same date, remaining low for the same period, rising at the same time, though to a much less degree—the maximum being 76 per haul—and then falling off rapidly to a low level which remains throughout the summer.

## VERTICAL DISTRIBUTION.

We have already shown above that our weighted open tow-net, ranging from about ten fathoms up to the surface during fifteen minutes, usually captured a larger quantity of plankton than the exactly similar surface nets hauled at the same time within a foot or two of the surface. This weighted net also, in most cases, caught more than the two vertical closing nets "Hensen" and "Nansen" (which, however, are not exactly comparable in size, either with the open tow-nets or with one another, see p. 138) hauled up as a rule through the zone of water from twenty fathoms to ten and then closed. In those cases, early in April, when either the Hensen or Nansen net showed a larger catch than the weighted net, the great bulk is seen

to be due to an excess of Diatoms in the vertical closing nets—thus showing that the protophyta are more abundant at that time in the lower layers of water. Larger organisms such as Medusae, Sagitta, Copepoda, Larvae and Fish Eggs are more abundant in the surface and the weighted nets—and more in the latter than in the former. We also find that, using similar open tow-nets, a net towed at a depth of a fathom or so catches more than one on the surface. At the time of the phyto-plankton maximum in spring it seems from the evidence of these various nets that the Diatoms are present in an increasing ratio as one descends from the surface to at least twenty fathoms; but that the Copepoda and other larger forms are most abundant in a zone within ten fathoms of, but below, the surface—probably in some cases only a fathom or two below it. For example we may quote the following particulars from Form 28, April 13th, which is not an extreme case, as the Diatom maximum is then past:—

| | Surface nets. | | Weighted net. (10-0 f.) | Hensen. (20-10 f.) | Nansen. (20-10 f.) |
|---|---|---|---|---|---|
| Total Diatoms ... | 6,500 | 6,650 | 11,000 | 96,000 | 290,000 |
| Total Copepoda ... | 1,970 | 1,880 | 3,180 | 66 | 335 |

Here the Diatoms are clearly most abundant in the depths and thin upwards; while the Copepoda are more abundant above and most abundant of all a few fathoms below the surface. Many of the Forms about this date show similar results. Later on, when the Diatoms have become much less abundant, the vertical closing nets bring up very little from the lower zones of water and are surpassed by all the other nets, e.g.—

| | Surface nets. | | Hensen. | Nansen. | Weight. |
|---|---|---|---|---|---|
| April 24—Station I. ..... | 20·5 | 15·5 | 0·5 | 2 | 16 c.c. |
| 24—Station II. ..... | 7 | 15 | 3 | 5 | 17·5 c.c. |
| 25—Station III. ..... | 5·5 | 4·5 | 1·5 | 2 | 20 c.c. |
| 25—Station V. ..... | 8 | 7·5 | 1 | 2·5 | 9·5 c.c. |
| 26—Station V. ..... | 4 | 4·5 | 0·5 | 0·75 | 8 c.c. |
| Aug. 21—Station I. ..... | 3 | 3 | 0·5 | 2 | 6·5 c.c. |

The last line shows that the same general proportions hold good in the latter part of August, when the catch is composed almost wholly of Copepoda.

In August some vertical hauls to the surface were made with the Hensen and Nansen nets out in deep water (60-70 fathoms), in mid-channel between the Isle of Man and Ireland, for comparison with similar hauls where the net was closed after having traversed some definite zone of water; and, as would be expected, the complete vertical hauls generally gave a larger result than the partial ones—except in a few cases where the haul was vitiated from the net apparently having gone so near bottom as to have taken in some mud stirred up by the weight.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Aug. | 24—Station A.—Nansen, | 60-50 | faths. | =0·3; | 60-35 | faths. | =0·5 | c.c. |
| | 24—Station B.— „ | 60-45 | „ | =0·2; | 60-0 | „ | =1 | „ |
| | 26—Station I.— „ | 25-15 | „ | =0·25; | 25-0 | „ | =1 | „ |
| | 31— „ — „ | 24-10 | „ | =0·7; | 24-0 | „ | =1·5 | „ |
| | 31— „ —Hensen, | 24-10 | „ | =0·3; | 24-0 | „ | =0·6 | „ |
| Sept. | 3— „ — „ | 20-10 | „ | =0·25; | 20-0 | „ | =0·75 | „ |
| | 3— „ —Nansen, | 20-10 | „ | =0·5; | 20-0 | „ | =0·7 | „ |
| | 4—Station A.— „ | 60-30 | „ | =0·5; | 60-0 | „ | =1 | „ |
| | 4—Station B.— „ | 60-30 | „ | =0·3; | 60-0 | „ | =0·75 | „ |
| | 4— „ —Hensen, | 60-30 | „ | =0·4; | 60-0 | „ | =0·5 | „ |

There were also hauls on the last date through the zone 60-50 which showed still smaller amounts, 0·05 to 0·1 c.c. An attempt was made to discriminate more minutely between the zones on a few occasions—e.g. September 12th, in 65 fathoms.

| | 60-50 | 60-30 | 60-0 | 30-20 | 20-10 | 10-5 |
|---|---|---|---|---|---|---|
| Hensen ..... | 0·1 | 0·1 | 0·25 | 0·1 | 0·15 | 0·25 |
| Nansen ..... | 0·2 | 0·3 | 1·2 | 0·15 | 0·3 | 0·2 |

These and other hauls confirm the opinion we arrived at, from the use of the open horizontal tow-nets at different depths, that the most abundant zone of life is about ten fathoms, or between that and the surface—say, between ten and five fathoms.

Finally, we used the "Mill" water-bottle on several occasions to get samples from three exact depths, with the following results:—

| | 20 faths. | 10 faths. | 5 faths. |
|---|---|---|---|
| **Sept. 17th—** | | | |
| Total organisms | 53 | 103 | 40 |
| Total Diatoms | 47 | 83 | 29 |
| Total Dinoflagellata | 3 | 12 | 6 |
| Total Copepoda | 3 | 8 | 5 |
| Chaetoceros teres | 1 | 3 | 1 |
| „ densum | 2 | 4 | 2 |
| Rhizosolenia semispina | 25 | 37 | 16 |
| „ stolterfothi | 12 | 26 | 9 |
| Coscinodiscus radiatus | 1 | 2 | 1 |
| Ceratium furca | 1 | 7 | 1 |
| „ fusus | 2 | 3 | 2 |
| **Sept. 18th—** | | | |
| Chaetoceros teres | 7 | 1 | 1 |
| Rhizosolenia semispina | 100 | 300 | 200 |
| „ shrubsolei | 1 | 1 | 2 |
| „ alata | 0 | 2 | 4 |
| „ stolterfothi | 1 | 1 | 2 |
| Coscinodiscus radiatus | 1 | 1 | 2 |
| Total Dinoflagellata | 11 | 32 | 9 |
| Pseudocalanus elongatus | 3 | 4 | 6 |
| Total Copepoda | 7 | 5 | 10 |
| Copepod nauplii | 10 | 20 | 30 |
| **Sept. 20th—** | | | |
| Chaetoceros subtile | 5 | 35 | 130 |
| Rhizosolenia semispina | 125 | 610 | 4,200 |
| „ alata | 1 | 6 | 40 |
| „ shrubsolei | 0 | 2 | 10 |
| „ stolterfothi | 1 | 4 | 10 |
| Total Diatoms | 132 | 672 | 4,470 |
| Total Dinoflagellata | 3 | 59 | 30 |
| Copepod nauplii | 1 | 18 | 60 |

These results are fairly consistent, and indicate a more abundant fauna in all groups at either ten or five fathoms than at twenty. On the 17th the fauna was at a lower level; the ten-fathom zone had over twice as much as the others, and the twenty was a little over the five. On the 18th also the fauna at ten fathoms predominated, but that at five fathoms came easily second. On the 20th the five-fathom fauna was much the most abundant and the ten-fathom came next. It seems as if during these days the centre of density was moving slowly upwards.

These observations should be repeated and extended,

but so far as they go they tend to establish the conclusion stated above as to the distribution of at least some elements of the plankton in zones of depth.

## HORIZONTAL DISTRIBUTION.

It is clear from an inspection of the Forms recording the 650 hauls now before us, that a much more detailed analysis than we can possibly give them before the publication of this Annual Report, will be necessary in order to arrive at any definite conclusions as to the relations between the results obtained horizontally at the different localities and dates. We recognise that we are far from having exhausted the information to be derived from these records; and the horizontal distribution, along with many other details of interest which we have noticed in the course of our work, must remain for some future occasion.

A mere inspection of the Forms shows in some cases close resemblances between adjacent stations (such as I and II) on the same day, or between adjacent days at the same station, and in other cases just as striking differences. How far these points of similarity and of divergence are normal and are fundamental, or how far they are due to wind, sun, and other weather conditions, or to tidal and other currents, will require detailed consideration.

We have several times been struck by the largeness of the hauls obtained, under very difficult conditions, in the strong tidal currents that race round the Calf Island. Such hauls are especially rich in Copepoda and other larger organisms of the plankton, and this observation is co-related with the well-known richness of the bottom and the littoral faunas in that same region, and agrees

with what has been recognised by naturalists for many years, that strong currents are favourable to a profuse development of animal life.

A further point that has struck us in the progress of this investigation is the obvious distribution of at least some organisms in shoals. This can occasionally be seen by the eye, when, for example, shoals of large Medusae are encountered which are so abundant for a limited area that on a calm day they may cover the surface like a tessellated pavement, and assume polygonal forms from mutual pressure. On other occasions our nets have evidently encountered swarms of Copepoda, of Cirripede Nauplii, of Crab Zoëas, of worm larvae or of other organisms. One might expect such results in the case of neritic forms, which are merely stages in the life-history of some gregarious organism; but the occurrence is by no means confined to such, it extends in our experience to oceanic organisms on the high seas, and this sporadic distribution in swarms has not been sufficiently taken into account by some writers who have treated of the distribution of the plankton in recent years.

The enormous quantities of the Diatom *Thalassiosira nordenskioldii*, Cleve, in our collections early in April (e.g. on April 4th 1,750,000, on April 5th 2,000,000, on April 8th 1,350,000 in single hauls) are a noteworthy feature. According to Gran ("Nordisches Plankton," Lief. III, xix, p. 16), this is a northern species found on the coasts of Northern Europe and the east coast of America. We have not met with it in the Irish Sea before. It might be argued that this was a case of a more northerly species carried down into our area by exceptional circumstances, or on the other hand the explanation may be that the Irish Sea is within the normal range of the organism, and that

special conditions have permitted of a quite exceptional development this year. In the latter case, however, it is curious that, considering all the plankton investigation that has been carried on at Port Erin and off the Lancashire coast during the last 20 years, the species has hitherto escaped notice. It appears to be present only very rarely at Plymouth and elsewhere in the English Channel (Blue-book, Cd. 3837, p. 228, 236, &c.).

## CONCLUSIONS.

We have expressed our opinions freely, both on general questions and on matters of detail, where they occurred to us in the course of writing the preceding pages, but it may be convenient to have summarised here the main conclusions at which we have arrived.

1. It is clear that many of the great seasonal variations in the plankton are not due to changes in the sea-water such as are recognised in hydrographic observations, but are caused simply by the normal sequence of stages in the life-histories of organisms throughout the year. No amount of "hydrographic" change in the water will determine the presence of Echinoderm larvae at a time of year when they are not produced, nor of Crab Megalopas when they do not naturally occur.

2. Three factors, at least, seem to us to require recognition as contributing to the constitution of the plankton from day to day throughout the year:—

(1) The sequence and periodicity of the stages in the normal life history of the organisms;

(2) Irregularities introduced by the inter-action of the organisms, as when one group serves as the food, or enemy, of another;

(3) Periodic changes and abnormalities of either time or abundance caused by the character of the sea-water or by weather conditions which may either determine or prevent the normal or permit of an abnormal development of certain species.

The appearance of swarms of Balanoid Nauplii, followed after an interval by the "Cypris" stage, is an example that comes under the first head. The disappearance of Diatoms when used as food by the increasing swarms of Copepoda and other Crustacea, both larval and adult, and of the Copepoda in turn when eaten by the developing post-larval fish, are changes falling under the second head. The great increase in the number of Diatoms in spring when the physical condition of the sea-water has become favourable, the enormous development of Dinoflagellates which may take place suddenly in autumn under unusual weather conditions, the almost total suppression of a group such as the Medusae in some localities in an unusually stormy summer, and the immigration of a species or a group of species from the open ocean or from a neighbouring sea-area as the result of variations in the hydrographic conditions, are all examples that may be classed in the third category.

Two, or all of these factors may, however, be at work together, and so the explanation of any particular change may be a very complicated problem. The increased development of a group, or the immigration of a species, may so disturb the balance of nature as to be followed by unusual changes in other groups.

3. Lists compiled from our results and curves drawn from these lists show that, as a consequence of the above factors, certain groups and certain prominent species differ from one another greatly in their relative abundance throughout the months of the year.

4. Thus, the Diatoms take on an enormous development in early spring, and reach their maximum in April, then die down during the summer, and may rise again to a second but much less important and less constant maximum in autumn. It must be borne in mind, however, that the species, and to some extent the genera, that form the autumn increase (*Chaetoceros subtile* and species of *Rhizosolenia*) are quite different from those present in spring (*Chaetoceros contortum* and species of *Thalassiosira*).

5. The Dinoflagellata rise to a maximum later than the Diatoms, and may have a second period of sudden increase in the autumn if weather conditions are favourable.

6. The Copepoda attain to their greatest development in early summer after the Diatoms have died down, and again in late autumn (October) they follow the phytoplankton. As a rule a haul rich in Copepoda has few Diatoms, and *vice versâ*; but the Copepoda do not, like the Diatoms, present great maxima and marked depressions. Even when both groups are present in the plankton we frequently find that they are in different zones; for example, in some of the April hauls in 1907 the Diatoms were markedly on the surface and the Copepoda below, while later in the year these positions were reversed.

7. The distribution of particular Copepoda (*Calanus*, *Anomalocera*, *Microcalanus*, *Centropages*, *Temora*, etc.) has been discussed, and for the full results we must refer to the body of this report. *Calanus*, *Centropages* and *Temora* are present throughout the year; *Anomalocera* appears in our district in spring; *Microcalanus* in late autumn.

8. Similarly the conclusions arrived at in regard to the distribution of *Sagitta*, *Tomopteris*, the Cladocera, *Oikopleura*, Cirripede Nauplii, and various other larval

forms and fish eggs are given in the preceding pages and need not be repeated here.

9. The Irish Sea contains a surprising number of what are usually regarded as "Oceanic" species—not merely as occasional visitants, but as normal and continuous constituents of the plankton during a great part of the year. Amongst these may be mentioned *Chaetoceros densum*, *Coscinodiscus radiatus*, *Rhizosolenia semispina*, *Ceratium tripos*, *Peridinium* sp., *Tomopteris onisciformis*, *Sagitta bipunctata*, *Pleurobrachia pileus*, *Calanus helgolandicus*, *Anomalocera pattersoni*, *Acartia clausi*, *Oithona similis*, and *Oikopleura dioica*. Some of these oceanic species seem, so far as we can judge from the published records, to be more abundant and more continuously present round the Isle of Man than they are even in the western part of the English Channel.

10. We have evidence from our closing vertical nets that the zone of most abundant life is not on the surface but is generally a few fathoms below—say, usually, between 5 and 10 fathoms. Samples of water from 5, 10 and 20 fathoms obtained with the "Mill" water bottle support the above statement. But this conclusion was arrived at, and could be established, quite apart from the evidence of the vertical nets, from a comparison of the results obtained by the weighted and surface open horizontal tow-nets.

11. At the time of the Diatom maximum in spring, however, our closing vertical nets showed that these Protophyta are more abundant in the deeper zones than at the surface, and increase in density downwards to at least 20 fathoms.

12. In the case of some groups, e.g. Cladocera and *Oikopleura* sp., the distribution is sometimes remarkably regular, the same numbers being taken simultaneously

by comparable nets at localities up to ten miles apart; but on the other hand even with these same groups there may, on other dates, be very diverse hauls indicating an uneven distribution.

13. Some species, and some groups of neritic larvae markedly congregate in shoals, and this also adds to the unevenness of the distribution.

14. The horizontal distribution of the plankton is consequently liable to be very variable and irregular, and although its characteristic constitution at different times of the year may be described, it is very doubtful whether any numerical estimates can be framed which will be applicable to wide areas.

15. It is clear that samples taken quarterly, monthly or even fortnightly are quite inadequate to convey a correct idea of the constitution and changes of the plankton of a sea-area in any detail; and, consequently, conclusions ought not to be drawn from such insufficient observations.

16. Our samples, taken weekly throughout the year, and almost daily during the three most critical months, give by no means too much information, but will probably suffice to enable us to make that detailed comparison between adjacent localities and dates which we hope to publish in the next Report with a view of determining the representative value of such periodic samples.

APPENDIX.

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# MEMOIR ON CANCER.

## The Edible Crab.

BY

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## Introduction.

Cancer is a genus which has a world-wide distribution. Only one species, however, is found in Europe, viz., *Cancer pagurus*, the subject of the present memoir.* This species is found on almost every part of the coasts of Europe from Norway to Greece, and it is particularly abundant on the shores of North-West Europe (France, Germany and the British Isles).

*Cancer pagurus*, the edible crab, has been chosen as the subject of the present memoir partly on account of its economic importance, and also because, as a type for dissection, it is easily procurable and is of a convenient size. The account given below, however, may be applied with very few alterations to any of the brachyurous Decapod Crustaceans, such as the common shore crab (Carcinus) or the swimming crab (Portunus).

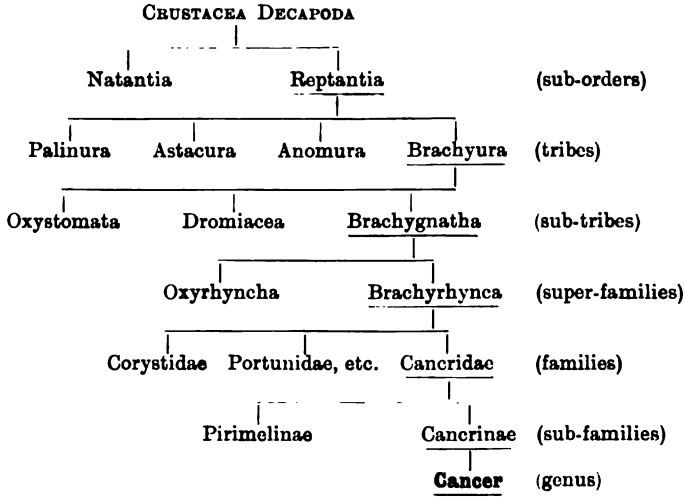
The edible crab is found in great abundance on the coasts of the British Isles, especially on those parts which are rocky, and gives rise to an important fishing industry. The large crabs live in fairly deep water, but the young representatives of this species may be readily obtained between tide-marks. Cancer is mainly carnivorous in its habits and feeding. It is particularly fond of dead fish, and it probably also feeds on other Crustaceans in a small degree. There is, however, no evidence to show that it has cannibalistic instincts. (For further particulars with regard to habits, distribution, crab fishery, &c., see section on Economics.)

*Cancer pagurus* was first named by Linneus, who established both the genus and the species. In his

* The investigation has been assisted by a grant of £25 from the Board of Agriculture and Fisheries, and the expense of producing the lithographed plates has been met in part by a grant of £30 from the "Treasury Grant for Research" of the University of Liverpool.

"Histoire naturelle des Crustacés," Milne-Edwards named it *Platycarcinus pagurus*. This latter name appears to have been retained in many continental works up to quite recent years.

I have followed the classification of Borradaile,* and I give below a table compiled from the results of his work.




The main characters of the various divisions of the Decapod Crustacea are given below.†

NATANTIA.—Rostrum well developed and compressed. Body compressed. First abdominal somite equal to rest. Stylocerite present. Second antennal scale large. In the legs basis and ischium never fused, and one fixed point in the carpo-propodal articulation. Male genital opening arthrodial. Abdominal limbs 1-5 well developed and used for swimming.

* Borradaile, L. A. "On the Classification of the Decapod Crustaceans." *Ann. and Mag. Nat. Hist.* (7), Vol. XIX, June, 1907.

† These characters are abstracted from Borradaile's paper.

REPTANTIA.—Rostrum reduced or absent, depressed if present. Body depressed. First abdominal somite smaller than rest. Stylocerite absent. Second antennal scale reduced or absent. In the legs generally a basi-ischium, and two fixed points in the carpo-propodal articulation. Male genital opening coxal and sternal. Abdominal limbs 1-5 reduced or absent, and not used for swimming.

The four tribes belonging to the Reptantia are divided into two groups.

I. Third legs like the first. Abdomen macrurous. Gnathobases of second maxillae narrow. Exopodites of maxillipedes with lash directed forward. Gills numerous.

(1) PALINURA.—Carapace fused to epistoma. Rostrum small or absent. Inner lobes of second maxillae and first maxillipedes reduced. Body depressed.

(2) ASTACURA.—Carapace free from the epistoma. Rostrum large. Inner lobes of second maxillae and first maxillipedes not reduced. Body subcylindrical.

II. Third legs unlike the first, never chelate. Abdomen rarely macrurous. Gnathobases of second maxillae broad. Exopodites of maxillipedes with lash directed inward. Gills few.

(3) ANOMURA.—Carapace not fused with epistoma. Last thoracic sternum free, its legs differing from the others. Abdomen anomurous. Movable antennal scale. Third maxillipedes narrow.

(4) BRACHYURA.—Carapace fused with epistoma. Last thoracic sternum fused with rest, its legs like the others. Abdomen brachyurous. No movable antennal scale. Third maxillipedes broad.

The following are the sub-tribes of the Brachyura:—

Oxystomata.—Mouth-field prolonged forward as a gutter. No female first abdominal limbs. Gills few. Female openings sternal.

Dromiacea.—Mouth-field square. First abdominal limbs present in female. Gills many. Female openings coxal.

Brachygnatha.—Mouth-field square. Female openings sternal. No first abdominal limbs in female. Gills few.

The Brachygnatha are divided into two super-families.

Oxyrhyncha.—Front part of body narrow. Distinct rostrum. Body more or less triangular. Orbits incomplete.

Brachyrhyncha.—Front part of body broad. Rostrum reduced or wanting. Body oval. Orbits complete.

The Brachyrhyncha are sub-divided into fourteen families. I give here the chief characters of the one family—the Cancridae.

Cancridae.—Marine crabs with the branchial region not greatly swollen. Carapace broadly oval or hexagonal. Rostrum often wanting. Orbits complete. Male openings coxal. Second antennal flagella short. First antennae folded lengthwise. Inner lobe on the endopodite in the first maxillipedes wanting. Legs generally not adapted for swimming.

The two sub-families of the Cancridae are as follows:—

Pirimelinae.—Carapace hexagonal. Epistoma sunken.

Cancrinae.—Carapace broadly oval. Epistoma not sunken.

## EXTERNAL CHARACTERS

(Pl. I, figs. 1, 2, 3).

The whole of the exterior of the animal is covered by a thick continuous chitinous exoskeleton or shell, which is highly calcified except between the movable somites of the abdomen and between the movable podomeres in the appendages.

The body may be conveniently divided into an anterior region—the Cephalon, a middle region—the Thorax, and a posterior region—the Abdomen. As in all the Decapoda the Cephalon and Thorax are fused to form the Cephalothorax.

The Cephalothorax is by far the largest portion of the body, and is the only part seen from the dorsal surface. The Abdomen is much reduced and is a flap-like structure closely applied to the ventral region of the cephalothorax between the bases of the walking legs.

There is every reason to believe that the crabs and their relatives have arisen from primitive Crustaceans having a body divided up into a number of movable segments or somites. Extreme specialisation has taken place, especially in the cephalothoracic region, and it is in the Abdomen that one sees the nearest approach to this primitive external segmentation. A careful examination, however, reveals the fact that there are *five* somites in the cephalic region, *eight* in the thorax and *six* in the abdomen—*nineteen* in all.

Before entering on a description of the more complex parts it will be useful to examine the structure of a typical abdominal somite.

The *third abdominal somite* of the female may be taken as a type (see text fig. 1).

This somite is flattened dorso-ventrally. On the

dorsal side there is thick and highly calcified exoskeleton, but the ventral wall is membranous.

The dorsal wall consists of a median portion—the **tergum** (text fig. 1, *t.*)—which is continued into two broad lateral portions—the **pleura.** The median ventral wall is known as the **sternum,** and from each of the outer portions of the sternum arises an appendage. Between the point of attachment of each appendage and the pleuron the ventral wall is known as the **epimeron.**

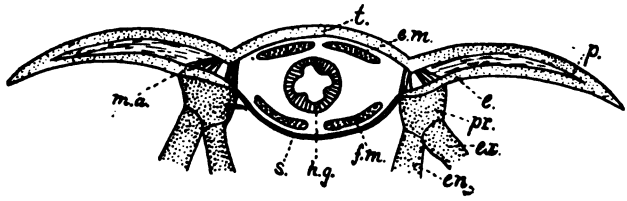



FIG. 1.—Diagrammatic section through female abdomen.

*t.* = tergum.
*p.* = pleuron.
*s.* = sternum.
*e.* = epimeron.
*e.m.* = extensor muscles of abdomen.
*f.m.* = flexor muscles of abdomen.
*m.a.* = muscles of abdominal appendage.
*h.g.* = hind gut.
*pr.* = protopodite.
*ex.* = exopodite.
*en.* = endopodite.

The segment is connected with the two neighbouring segments by a thin uncalcified part of the exoskeleton—the **arthrodial membrane.** This allows of free movement between the segments. Each segment articulates with the one in front by means of a pair of hinges placed at the outer and anterior part of the pleuron at each side.

The appendages will be described in detail later.

## CEPHALOTHORAX.

### 1. Carapace.

The terga and pleura of the cephalothorax are fused to form the large Carapace. This is a broad shield the width of which is about $1\frac{1}{2}$ times as great as the length.

Instead of taking an even sweep downwards the carapace passes outwards almost horizontally and then suddenly bends inwards and passes down to the bases of the walking legs. An examination of a rough section of the animal will show that at the base of the legs the carapace turns suddenly upwards and is continuous with the membranous wall of the spacious **Branchial Chamber** (Pl. IV, fig. 56, *br. ch.*). The space between the ventral part of the carapace and the base of the legs is so very small, and moreover is so well guarded by long setae that no water can enter the branchial chamber at this border, as is the case in the Macrura. There are, however, two openings into the branchial chamber—the small *posterior inhalent branchial aperture*, above the coxopodite of the last pereiopod, and the larger *anterior inhalent branchial aperture*, situated immediately in front of the coxopodite of the chela. The ventral part of the carapace turns forward in front of the latter opening, and passing around the mouth it fuses with the pre-oral cephalic sterna. The portion of the carapace which passes around the mouth is turned inwards at each side to form a chamber which lies immediately in front of the Branchial Chamber. This may be called the **Pre-branchial Chamber.** Its roof is membranous and is fused on its inner side with the epistoma and with the endopleurites of the two post-oral cephalic somites, and probably represents the epimera of the third, fourth and fifth cephalic somites. The Pre-branchial Chamber will be described in detail in the section on Respiration.

Both the dorsal and the inflected portions of the lateral region of the carapace were designated the "branchiostegite" by Milne-Edwards because they enclose the branchial cavity.

Anteriorly the dorsal surface of the carapace is

bounded by a median portion between the orbits and two lateral portions. Similarly the posterior boundary consists of a median portion and two lateral portions. So that we may speak of these borders as the anterior, antero-lateral, posterior and postero-lateral respectively.

The **Anterior Border** is situated between the orbits. The *rostrum*, which occupies the median portion of this region, consists of a median and two lateral lobes. It is continued ventrally as a median plate which separates the two cavities in which are lodged the eye peduncles. Each of the lateral lobes of the rostrum passes downwards as the *supraciliary lobe*, which fuses with the anterior and inner region of the second antenna (Pl. III, fig. 20, *S.l.*). Passing outwards from the rostrum the anterior border of the carapace divides at each side into the supra-orbital and infra-orbital portions which form the boundary of the orbit. On its inner side the supra-orbital edge has the prominent *supra-orbital lobe* which is close to the lateral lobe of the rostrum. The inner boundary of the orbit is fused with the outer portion of the second antenna.

The **Antero-lateral Borders** form an arc of a circle the centre of which is at the junction of the two outer grooves bounding the epibranchial region of the carapace (see below). Each antero-lateral border is divided up into nine lobes by well-defined ridges. There is no definite distinction between the antero-lateral border and the postero-lateral border, but the latter may be said to commence at the posterior end of the ninth lobe. There is also a feebly marked lobe on the outer portion of the postero-lateral ridge.

The **Postero-lateral Border** passes backwards and inwards. This border is well rounded and not so clearly defined as the anterior and antero-lateral borders.

Immediately in front of this border there is the

*postero-lateral ridge*, which is continuous on its outer side with the antero-lateral border. At its outer edge it is coincident with the postero-lateral border, but as it passes inwards it becomes quite distinct from the latter and dies away near the median line in front of the posterior border.

The **Posterior Border** of the carapace is horizontal, and is continuous behind with the tergum of the first abdominal segment.

Areas of the Carapace. (Text fig. 2.)

The dorsal surface of the carapace is divided up by means of small depressions into areas.

The *Cervical groove* (*C. gr.*) separates the cephalic region of the carapace from the thoracic region. This groove is seen as a transverse median depression a little more than half way down the carapace. The width of this median groove is almost equal to the distance between the two supra-orbital lobes.

At each of its outer edges the median groove is continuous with a well-marked depression which commences at the posterior end of the fifth lobe of the antero-lateral border. This depression is curved, the convexity being in front. The median groove and its two lateral extensions together form the cervical groove.

The Cephalic portion of the carapace is divided into the Facial and Gastric regions.

The Facial region is separated from the rest of the cephalon by a faint transverse depression near the front of the carapace. The outer ends of the depression bend forward and terminate on the second lobe of the antero-lateral border. This region is divided into a median **Frontal** region (*Fr.*) and two lateral **Orbital** regions (*Orb.*).

The Gastric region is bounded behind by the

Cervical groove, and is composed of a median triangular portion having the apex pointing backwards and two lateral portions which end at the antero-lateral border. The median portion is divided into two anterior **Protogastric** regions (*Pg.*), a median anterior **Mesogastric** region (*Mg.*), a pair of posterior **Metagastric** regions (*Mtg.*), and a median posterior **Urogastric** region

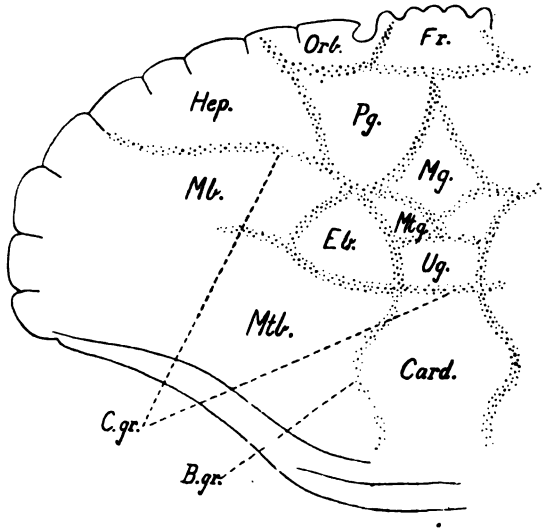



FIG. 2.—Areas of the Carapace.

*Fr.* = Frontal region.
*Orb.* = Orbital ,,
*Hep.* = Hepatic ,,
*Pg.* = Protogastric ,,
*Mg.* = Mesogastric ,,
*Mtg.* = Metagastric ,,
*Ug.* = Urogastric ,,
*Mb.* = Mesobranchial region.
*Mtb.* = Metabranchial ,,
*Eb.* = Epibranchial ,,
*Card.* = Cardiac ,,
*C.gr.* = Cervical groove.
*B.gr.* = Branchio cardiac groove.

(*Ug.*). The lateral portions are known as the **Hepatic** regions (*Hep.*). Each extends outwards to the antero-lateral border and is bounded behind by the outer part of the cervical groove.

The Thoracic portion comprises that part of the carapace which lies behind the cervical groove. It is

divided by two longitudinal grooves—the *Branchio-cardiac grooves* (*B.gr.*)—into a median **Cardiac** region (*Card.*) and two lateral branchial regions. Each branchial region is made up of an anterior **Mesobranchial** region (*Mb.*) and a posterior **Metabranchial** region (*Mtb.*) and a small inner **Epibranchial** region (*Eb.*).

The ventral inflected portion of the carapace is divided into two parts by a well defined groove, which may be termed the *pleural groove*, as it probably marks the separation between the cephalo-thoracic terga and pleura. It is along this groove that the carapace splits during ecdysis (see section on Ecdysis). The pleural groove commences at the epistoma and passes outwards and slightly backwards until it almost reaches the posterior end of the seventh lobe of the antero-lateral border. Here it turns backward and runs parallel to the postero-lateral ridge, finally reaching the posterior border with which it becomes continuous. Thus the pleural groove divides the inflected portion of the carapace into an outer, or **Sub-hepatic** region, and an inner, or **Sub-branchial** region. The sub-hepatic region may be considered as an inflected portion of the tergum, and the sub-branchial as belonging to the pleural region. Milne-Edwards regarded the sub-branchial region as part of the cephalo-thoracic epimera, but the inner walls of the branchial chambers undoubtedly represent the epimera.

## 2. Pre-oral Cephalo-thoracic Sterna.

(Pl. III, figs. 19, 20.)

Ventrally the median lobe of the rostrum passes backwards as a triangular plate, the apex of which points posteriorly. This plate, which is separated at its posterior end from the first sternum [antennulary sternum] ($S^1$)

by a well-defined suture, forms a septum* between the articular cavities of the two optic peduncles.

From the dorsal side of the sternal region the septum between the above-mentioned articular cavities is short and broad. On a level with the posterior end of these cavities there is a well-marked suture separating the septum from the first sternum.

Immediately in front of the dorsal side of the ophthalmic articular cavities (*o.m.c.*) are two short calcareous plates near the median line, which stretch across to the roof of the carapace. These are the *Procephalic processes* (*p.c.p.*) to which are attached the anterior gastric muscles.

**The First Sternum** ($S^1$) lies in the segment of the first antennae (*ant$^{le}$.*) and separates the articular cavities of these appendages. Owing to the depth of the sternum in this region its relationship to the articular cavities is best seen from the dorsal side of the sternum.

It consists of a median piece lying between the articular cavities of the antennules, and of two lateral expansions which form the posterior boundaries of the articular cavities. Viewed laterally the sternum is seen to have a comparatively great depth. About half way down the anterior face of this sternum is a concavity into which fits a process from the septum between the ophthalmic articular cavities.

From the ventral side the first sternum bounds the posterior and inner sides of the sockets of the antennules, and the lateral prolongations extend as far as the bases of the second antennae.

* In the present Memoir the optic peduncles are not regarded as modified appendages, and I shall not regard the region of the body from which the eyes arise as the first segment, nor shall I speak of the septum between the articular cavities of the optic peduncles as the first sternum.

Huxley* in his short account of the crab states that the ophthalmic and antennulary sterna are fused, and that the suture is between the fused sterna and the rostrum. I am of the opinion that the whole of the sternum behind the suture belongs to the antennulary somite alone, and that the septum separating the articular cavities of the optic peduncles is a posterior prolongation of the rostrum, as described above. An examination of the sternum from the dorsal side (Pl. III, fig. 19) shows that the suture is on a level with the posterior boundary of the ophthalmic articular cavity; so that, if Huxley's view be accepted, we have the ophthalmic sternum entirely behind the articular cavity of its own somite! It is much more reasonable to conclude that the suture separates the ophthalmic septum from the antennulary sternum.

**The Epistoma** is a broad plate in front of the mouth and immediately behind the first sternum. It represents the united sterna of the second (antennary) ($S^2$) and third (mandibular) ($S^3$) somites. Its anterior border is concave in front. The two lateral borders gradually slope inwards towards their posterior ends. The posterior border is deeply concave behind and bounds the front edge of the mouth.

The middle part of the anterior border touches the posterior edge of the first sternum and the two outer portions bound the posterior edge of the second antenna. The lateral borders are in contact with the membranous roof of the pre-branchial chamber.

From the middle of the anterior border of the ventral side of the epistoma a median groove passes backwards but does not extend as far as the posterior border. From

* T. H. Huxley, *Manual of the Anatomy of Invertebrated Animals*, 1877, pp. 340-345.

the posterior edge of this groove a slight depression passes outwards at each side parallel to the anterior border. This depression probably marks the boundary between the antennary and mandibular sterna. This groove is better defined on the dorsal side of the epistoma.

The **Labrum** (Pl. III, fig. 20, *lab.*) is a soft fleshy lobe attached to the middle region of the posterior border of the epistoma. It is surrounded near the middle by a calcareous ring which gives off a median posterior prolongation. At each side of this median plate is a soft fold.

### 3. Post-oral Cephalo-thoracic Sterna (Pl. I, figs. 2, 3, Text fig. 3).

These are all fused together as a single oval-shaped plate situated between the bases of the paired post-oral cephalothoracic appendages. Transverse grooves are present which mark the division of this region into segments or somites, and which mark the places at which the sterna grow inwards to form the endosternites of the endophragmal system.

The surface of the fused sterna is concave laterally in order to accommodate the abdomen, which is always in a flexed condition. This concavity is especially well marked in the males. The surface of the sterna is, however, convex antero-posteriorly.

On the sternum of fifth thoracic somite are two small tubercles (*P.*) which fit into two concavities on the abdomen and thus form an effective locking apparatus which keeps the abdomen in position. These are especially large in the males.

The sternum of the sixth thoracic somite of the female bears a pair of large openings which are the external genital openings.

The sterna of the last four thoracic somites are characterised by a median groove which marks the place at which the " Median plate " of the endophragmal system has grown inwards. The anterior end of this median groove is marked by a very deep depression which is situated at the posterior end of the fourth thoracic sternum.

At the outer and posterior corners of each sternum are backwardly directed areas--the " episterna "

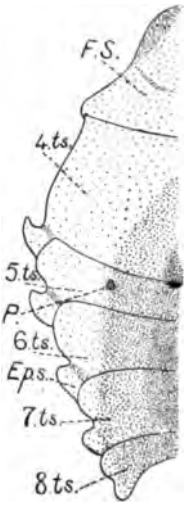



FIG. 3.—Ventral view of post-oral cephalothoracic sterna (male).

*F.S.* = Fused sterna of the two post-oral cephalic and the first three thoracic somites. *4.ts.*—*8.ts.* = Sterna of the 4th to 8th thoracic somites. *Ep.s.* = Episternum. *P.* = Sternal papilla of the abdominal locking apparatus.

(*Eps.*) which run for a short distance alongside the following sternum, from which they are separated by distinct sutures. Between each episternum and the corresponding sternum is a slight groove which is not very distinct in the edible crab. In Portunus and other crabs, however, this groove is much more distinct so as to suggest a complete separation between the sternum and episternum. This probably explains why Brooks* states

* Brooks, *Handbook of Invertebrate Zoology.*

that the episternum is *anterior* to the outer end of its own sternum. He has evidently mistaken the groove mentioned above for a true suture, and has therefore concluded that the episternum belongs to the following sternum. The last thoracic sternum has no episterna.

At the anterior end of each episternum is a small concavity into which fits the ventral hinge of the coxopodite of the appendage of that somite.

The sterna of the last two cephalic and the first four thoracic somites (*F.S.*) are fused together, without any sign of separation into distinct segments as in the posterior region of the thorax.† There is, however, a slight evidence of a division in front of the fourth sternum of the thorax.

That portion of the thoracic sterna which is covered by the abdomen is characterised by the absence of setae. There are long setae along the outer edges of the episterna, and also on that portion of the fused sterna belonging to the two last cephalic segments and the first four thoracic segments.

In front of the fourth thoracic sternum the outer edges of the sterna are turned up vertically.

The first post-oral cephalic sternum has two lateral processes which project forwards and give support to the **Metastoma.** The metastoma is a fleshy lobe forming the posterior lip of the mouth.

### 4. Cephalic epimera.

In the first two cephalic somites it is difficult to identify the epimera, but the latter are probably represented by the region between the outer portion of the articular cavities of these somites and the carapace.

† The two post-oral cephalic sterna, which are represented by two narrow bars at the extreme anterior end of the fused post-oral sterna, are separated from each other, however, by transverse sutures.

The epimera of the third (mandibular) and the two last cephalic somites (maxillary) are probably represented by the membranous roof of the pre-branchial chamber at each side (Pl. III, fig. 18, *r.br.*). This is continuous behind with the thoracic epimera.

### 5. Thoracic epimera

(Plate III, fig. 18, *epm.* 6-12).

The thoracic epimera are represented by a continuous plate at each side forming the inner wall of the branchial chamber. This is the "flanc" of Milne-Edwards. The lower border of the epimera commences immediately above the base of the thoracic appendages. They pass upwards and inwards and are continuous above with the membranous roof of the branchial chamber. At the posterior end they extend upwards almost to the carapace, from which they are only separated by short muscles which pass from the summit of the epimera to the carapace. At the anterior end the epimera are much shallower and become continuous with the roof of the branchial chamber some distance below the carapace.

The fused thoracic epimera form an extremely convex wall which is divided up into segments by vertical sutures, which correspond to the lines of separation between the various somites of the thorax. In this way the epimera are divided up into seven portions. The epimera of the first and second thoracic somites are completely fused, and there is no groove separating them, but apart from this there is one segment of the fused epimera for each of the remaining thoracic somites. The epimeron of the fourth somite is particularly broad. That of the last thoracic somite is not bounded posteriorly by

a groove, but is continuous with the sternum of the same segment.

In their natural position the gills lie upon the thoracic epimera.

## The Abdomen.

The abdomen is continuous with the posterior part of the cephalothorax. The connection is effected by means of an arthrodial membrane, which allows of considerable movement between the two regions. The abdomen is small and in its natural position is closely applied to the sternal region of the thorax. This region differs in the two sexes, being much broader in the female than in the male. This character provides a useful and ready method of distinguishing between the two sexes. There are other differences which require a more detailed examination.

### Female.

(Pl. I, fig 2, Pl. IV, fig. 32, Pl. V, fig. 34.)

This consists of six somites and the telson, all of which are freely movable. When lying in position it extends as far forward as the posterior end of the sternum of the third thoracic somite. The locking arrangement for keeping the abdomen closely applied to the thoracic sternum is not so well developed as in the male. It consists of two extremely small tubercles on the fifth thoracic sternum which fit into two slight depressions at the postero-lateral corners of the ventral side of the sixth abdominal somite. The total length of the abdomen is $2\frac{1}{2}$ times as much as its greatest width.

There are four pairs of appendages, one pair being borne on the second and on each of the three following somites, respectively.

On the dorsal side of the abdomen the terga are separated from the pleura by two longitudinal grooves. Ventrally the median portion is covered by a thin uncalcified cuticle and the outline of the hind-gut is clearly seen.

The hind-gut opens on the ventral side of the telson at the *anus*.

Only the first somite requires any special comment. The upper side of this somite is prolonged forward as a thin triangular flap, the apex of which points anteriorly. This triangular portion is covered by the carapace, only a narrow region at the posterior end of the somite being exposed. All around the anterior edge of this somite is a thin membrane which is continuous with the posterior region of the cephalothorax.

The first two somites are hollowed out laterally to provide free movement for the last pair of thoracic legs.

### Male (Pl. I, fig. 3).

When lying in position the abdomen extends slightly in front of the middle of the fourth thoracic sternum. It is slightly shorter than the female abdomen and much narrower. As in the latter, the sides of the first two somites (and also part of the third) are hollowed out and pass round the inner sides of the last pair of thoracic appendages.

The first somite has the same arrangement as in the female. The anterior part of the dorsal side is triangular and is covered by the carapace.

The third, fourth and fifth somites are fused together so that there is absolutely no movement between them. The sutures marking their separation still persist.

There are only two pairs of appendages which are present on the first and second somites respectively.

These appendages are peculiarly modified to act as copulatory organs (see sections on Appendages and Reproductive System).

The male abdomen is much more closely applied to the thorax than is the case in the female. This is partly due to the small number of appendages and also to the very effective locking apparatus. The latter is similar to that described in the female and the position of the parts is the same, but the tubercles on the thoracic sternum are much larger, as is also the case with the concavities on the sixth abdominal somite.

Below are given the measurements of the abdomen of a male and female, both having a carapace breadth of 23·5 cm.

| No. of Somite. | Female. | | Male. | |
|---|---|---|---|---|
| | Greatest length. | Greatest width. | Greatest length. | Greatest width. |
| | mm. | mm. | mm. | mm. |
| 1 | 17 | 25 | 17 | 22 |
| 2 | 8 | 22 | 8 | 17 |
| 3 | 7 | 30 | 7 | 23 |
| 4 | 8 | 32 | 8 | 20 |
| 5 | 10 | 35 | 9 | 17 |
| 6 | 20 | 35 | 13 | 16 |
| Telson | 18 | 21 | 13 | 13 |
| | Total length, 88 mm. | | Total length, 75 mm. | |

## External apertures.

The external openings are as follows:—

The **Mouth**—a median aperture on the ventral side of the cephalic region between the mandibles.

The **Anus**—a median aperture on the ventral side of the telson.

The **Excretory Openings**—one pair. These are situated at the base of the second antennae on the ventral side. Each is covered by an operculum.

The **Female Reproductive Openings**—one pair. These are two large apertures on the sternum of the sixth thoracic somite.

The **Male Reproductive Openings**—one pair. These are situated on the ventral side of the coxopodites of the last pair of thoracic appendages.

### Appendages (Plate II).

There are five pairs of appendages on the head and eight pairs on the thorax. There are four pairs of abdominal appendages in the female and only two pairs in the male. The appendages are as follows:—

| | | | |
|---|---|---|---|
| Cephalon. | Somite | I.—1st Antennae (Antennules). | |
| | ,, | II.—2nd Antennae. | |
| | ,, | III.—Mandibles. | |
| | ,, | IV.—1st Maxillae. | |
| | ,, | V.—2nd Maxillae. | |
| Thorax. | Somite | VI.—1st Maxillipedes. | |
| | ,, | VII.—2nd Maxillipedes. | |
| | ,, | VIII.—3rd Maxillipedes. | |
| | ,, | IX.—1st Pereiopods. | |
| | ,, | X.—2nd Pereiopods. | |
| | ,, | XI.—3rd Pereiopods. | |
| | ,, | XII.—4th Pereiopods. | |
| | ,, | XIII.—5th Pereiopods. | |
| | | *Female.* | *Male.* |
| Abdomen. | Somite | XIV.—Absent. | 1st Pleopods. |
| | ,, | XV.—1st Pleopods. | 2nd Pleopods. |
| | ,, | XVI.—2nd Pleopods. | Absent. |
| | ,, | XVII.—3rd Pleopods. | Absent. |
| | ,, | XVIII.—4th Pleopods. | Absent. |
| | ,, | XIX.—Absent. | Absent. |

**The First Antenna or Antennule** (Pl. II, fig. 4, Pl. III, fig. 20) is situated in a deep depression on the ventral side of the cephalic sternum (*s.a.*[1]). This depression or socket is bounded in front by the rostrum (*rost.*), and behind by the lateral expansion of the first sternum ($S^1$). The outer boundary is formed by the inner edge of the second antenna (*ant.*), and the inner boundary by the median portion of the first sternum. The appendage consists of a broad basal joint, from which is given off on its inner side a two-jointed portion. These three pieces together form the *protopodite* (*prot.*). From the end of the distal segment of the protopodite arise two many-jointed flagella—an inner *endopodite* (*end.*) and an outer *exopodite* (*ex.*). The exopodite is the larger of the two, and bears on its inner side a tuft of long setae. The "olfactory" setae are small setae on the ventral side of the exopodite (see section on Sense Organs).

On the dorsal side of the basal segment of the protopodite is a longitudinal groove covered with long setae. This groove marks the place where the auditory sac opens to the exterior in the young animal. In the adult crab this groove is completely closed, although it remains open a short time after ecdysis.

In their natural position the three parts of the protopodite are folded on one another. The second segment is closely applied to the inner side of the basal segment. The third segment is bent back along the dorsal side of the second, and its distal end lies in an excavation made for its reception in the dorsal wall of the basal segment.

**Second Antenna** (Pl. II, fig. 5, Pl. III, fig. 20). This consists of a large basal portion (*prot.*) which is fused to the carapace, and a distal flagellum, which consists of two long basal segments and a number of short rings,

arising from the anterior and inner region of the basal portion. At the posterior and outer corner of the large basal segment is the operculum (*op.*), which covers the external excretory opening. This operculum probably represents the *coxopodite* and the larger basal portion the *basipodite*, the two together forming the *protopodite*. The flagellum probably represents the *endopodite*.

The outer edge of the basipodite is fused to the subhepatic region of the carapace. Backward processes from the supraciliary (*S.l.*) and supra-orbital lobes fuse with the anterior end of the basipodite. The inner and posterior corner of this segment is in contact with the lateral portion of the first sternum, and the posterior border of the same segment is in contact with the epistoma.

**The Mandible** (Pl. II, fig. 6) lies at the side of the mouth. The main portion is an elongated strongly calcified structure which is divided into two parts—an inner part, which projects over the ventral region of the mouth, and acts as the "jaw," and an outer part, the *apophysis* (*apoph.*), to which are attached the tendons of the mandibular muscles. At the outer extremity is the tendon of the external adductor (*t.ex.ad.*). Behind this, attached to a small projection, is the tendon of the external abductor (*t.ex.ab.*). To the posterior and inner side of the apophysis is attached the tendon of the internal adductor (*t.int.ad.*). The internal abductor arises from the apophysis on the inner side of the base of the tendon of the external adductor. There is no tendon for the internal abductor. Anteriorly the mandibular palp (*md. palp.*) arises from the inner side of the apophysis. The mandible is hinged to the epistoma by means of a small projection below the palp. There is no definite hinge posteriorly, but the posterior border of the inner region

of the apophysis is attached to the metastoma by means of a somewhat flexible membrane.

**The First Maxilla** (Pl. II, fig. 7, Pl. IV, fig. 26), which arises immediately behind the mandible, is small and is made up of a *protopodite* and *endopodite*. The exopodite is absent. The protopodite is on the inner side and is composed of two distinct pieces—a narrow proximal *coxopodite* (*C.*) and a larger *basipodite* (*B.*) which is external to the coxopodite. The *endopodite* (*end.*) arises from the outer side of the basipodite, and consists of a broad proximal leaf-like region and a narrower distal region. From the distal extremity of both parts of the protopodite arise fairly strong setae.

**The Second Maxilla** (Pl. II, fig. 8, Pl. IV, fig. 27) consists of an inner *protopodite*, a median *endopodite* (*end.*) and an outer *exopodite* (*Scaph.*). The protopodite is composed of a *coxopodite* (*C.*) and a *basipodite* (*B.*), each of which is bilobed. The two lobes of the coxopodite are long and slender, and are clearly separated from one another. Those of the basipodite are broader, and the separation between the two lobes is only partial. On the outer side of the basipodite is the small endopodite, which ends in a long narrow process. On the outer side of the endopodite and arising from the basipodite, is the large modified exopodite which is known as the *scaphognathite* (*Scaph.*). This is a broad plate of irregular shape which lies in the pre-branchial chamber. By means of its rapid and complicated movement it bales the water out of the branchial chamber.

In the **First Maxillipede** (Pl. II, fig. 9) the protopodite is on the inner side. The *coxopodite* (*C.*) is small and richly clothed with setae, and the *basipodite* (*B.*) is a long lamella having two rows of setae on its outer edge. The *endopodite* (*end.*) is between the exopodite and the proto-

podite. It is membranous, the proximal half being flattened laterally and the distal half dorso-ventrally. The *exopodite* (*ex.*) is long and slender and consists of a long proximal segment, which is as long as the endopodite, and a distal many-jointed flagellum (*flag.*) which in its natural position projects inwards at right angles to the proximal segment. During life this flagellum is exceedingly active. From the outer side of the protopodite arises the long *flabellum* (*flab.*) (or epipodite). This is a long narrow membranous plate which passes back into the branchial chamber above the gills. The proximal portion of the flabellum is broad and leaf-like.

The **Second Maxillipede** (Pl. II, fig. 10) has the exopodite and flabellum in the same position as in the previous appendage. The flabellum (*flab.*), however, is much shorter than that of the first maxillipede, and lies along the upper portion of the thoracic epimera and below the gills. The protopodite is much reduced, but the proximal *coxopodite** (*C.*) and the distal *basipodite* (*B.*) can still be made out. The endopodite is comparatively larger than the same part in the first maxillipede. It arises from the basipodite and is divided into five movable segments. The first or proximal segment—the *ischiopodite* (*I.*) is small. The second segment or *meropodite* (*M.*) is the longest, and equal in length to the other four segments. The three distal segments are small, and between the second and third segment the endopodite turns inwards, the distal segments being at right angles to the meropodite. The names of the third, fourth and fifth segments are *carpopodite* (*C.*[1]), *propo-*

* The following abbreviations are sometimes used:—*coxa* = coxopodite; *basis* = basipodite; *ischium* = ischiopodite; *meros* = meropodite; *carpos* = carpopodite; *propos* = propodite; *dactylos* = dactylopodite.

*dite* (*P.*) and *dactylopodite* (*D.*) respectively. Arising from the appendage immediately in front of the base of the flabellum is a *podobranch* (*pod. br.*) (see section on Respiratory Organs).

The **Third Maxillipede** (Pl. II, fig. 11, Pl. IV, fig. 30) is built on a similar plan to the previous appendage. The basis and the ischium are fused together to form the *basi-ischium* (*B.-I.*). The podobranch (*pod. br.*) is very small and arises from the coxopodite. The flabellum (*flab.*) lies on the lower part of the thoracic epimera below the gills. The endopodite and exopodite (*ex.*) are closely applied together and are much flattened so as to form with the same appendage of the other side an effective operculum closing over the remaining mouth parts, and preventing the exhalent current of water from the branchial chamber from passing out except in front of the scaphognathite.

The mandibles, maxillae and maxillipedes all lie around the mouth in the large depression between the anterior parts of the sub-branchial regions of the carapace. The ventral side of the third maxillipedes is on a level with the sub-branchial region. As the flabellum of this appendage passes back into the branchial cavity, it passes along the front of the anterior inhalent branchial aperture, and reduces the size of the aperture considerably. At this point the flabellum* is also richly clothed with strong setae, which probably act as a "strainer" in conjunction with the setae present on the front part of the coxa of the chela (see section on Respiratory Organs).

The **First Pereiopod** (or chela) (Pl. II, fig. 12, Pl. III,

* The coxopodite of the third maxillipede is prolonged outwards, and bounds the inner part of the inhalent aperture. The flabellum bounds the outer part. Both are richly clothed with setae on their posterior faces.

fig. 21) is the largest appendage in the body. It consists of seven segments (or podomeres). A comparison with the third maxillipede indicates that the two proximal segments belong to the protopodite, and the remaining five to the endopodite. There is no exopodite present. The seven segments have the same names as the similar parts in the third maxillipede. With the exception of the second and third segments, which are fused together to form the *basi-ischium* (*B-I.*), all the parts are freely movable. The basi-ischium has a thin groove running around it, which marks the separation of this fused portion into its two constituent parts. This groove is known as the *fracture plane* because it is at this point that the animal fractures the limb during the process of self-amputation (see section on Autotomy). The two distal segments of the limb are slightly modified to form the pincer which constitutes an effective prehensile organ.

Each of the movable segments swings in a different plane, so that the combined movement of the whole appendage is a very complete one. The coxopodite (*C.*) articulates with the body by means of two hinges, one being dorsal (Pl. III., fig. 21, *d.*) and the other ventral (*v.*). The dorsal hinge is attached to the antero-ventral corner of the epimeron of the fourth thoracic somite, and the ventral hinge articulates at the postero-lateral corner of the sternum of the same segment. Thus the motion of the coxopodite is in a horizontal plane, moving backward and forward. The fused basi-ischium (*B.-I.*) articulates with the coxa by an antero-dorsal ($d^1$) and a postero-ventral hinge ($v^1$), and the movement is upwards and downwards in a plane making an angle of about 45° with the vertical. The meros (*M.*) has very little movement. Its two hinges are antero-dorsal ($d^2$) and postero-ventral respectively ($v^2$), and the small degree of movement of

which this segment is capable is almost in a vertical plane. The two hinges of the carpos (*C.*[1]) are situated dorsally ($d^3$) and ventrally ($v^3$), and the segment moves forward and downward. The propodite (*P.*) has two hinges—dorsal ($d^4$) and ventral ($v^4$). The former is external to the latter, and the segment moves forward and slightly upward. In the dactylos (*D.*) the hinges are horizontal and the segment swings in a vertical plane.

The dimensions of the various segments of the chela in a female crab (carapace breadth 23·5 cm.) are as follows:—

| | Anterior length. | Posterior length. |
|---|---|---|
| Coxopodite ... ... | 7 mm. ... | 11 mm. |
| Basi-ischiopodite ... | 17 „ ... | 6 „ |
| Meropodite ... ... | 19 „ ... | 32 „ |
| Carpopodite... ... | 10 „ ... | 30 „ |
| Propodite ... ... | 50 „ ... | 20 „ |
| Dactylopodite ... | 20 „ ... | 30 „ |

The dorsal sides of the basi-ischium and of the meros are flattened so that they can be closely applied to the anterior portion of the sub-branchial and sub-hepatic regions of the carapace, and in these places setae are absent from the carapace.

Between the meros and the carpos the limb is capable of bending on itself, so that the anterior borders of the propodite and the carpos become closely applied to the anterior borders of the basi-ischium and the meros.

On the dorsal side of the basi-ischium and meros there are irregular grooves. These are the lines of absorption (Pl. II, fig. 12, *abs.*) (see section on Ecdysis).

**Pereiopods 2-5** (Pl. II, fig. 13). These are known as the "walking legs." Their essential structure is the same as that of the chela. The one obvious difference is that in all the walking legs the propodite has not an

outgrowth which, in conjunction with the dactylos, forms a pincer. In other words, the walking legs terminate in a single claw, and are not chelate.

The three terminal segments are capable of being flexed upon the proximal segments. This flexion is in a vertical plane.

**Pleopods** (Female) (Pl. II, fig. 17). There are four pairs of appendages on the female abdomen, one pair being situated on each of the second, third, fourth and fifth somites respectively. They are all similar in structure. Each pleopod is attached to the abdomen by a basal piece—the *protopodite* (*prot.*). From this arise two long pieces—an outer *exopodite* (*ex.*) and an inner *endopodite* (*end.*). The exopodite is almost cylindrical in section, and about half as long as the abdomen.

From the outer and inner edges of the exopodite rows of setae arise. Each seta has short fine branches given off from each side of the central stem. The endopodite is about as long as the exopodite. About one-third of its length from the base is a well-defined transverse groove. The setae are arranged, as in the exopodite, along the outer and inner edges, but they arise in small bundles. The setae are very long and do not bear offshoots except near the tip, where there are a few very fine short branches. The eggs are attached to the endopoditic setae.

**Pleopods** (Male) (Pl. II, figs. 14, 15, 16). There are two pairs of abdominal appendages in the male, which are situated on the first two somites. Both pairs are greatly modified and act as copulatory organs (see section on Reproductive Organs).

*First pair* (Pl. II, fig. 14). Each consists of two parts—a broad basal portion, probably the *protopodite* (*prot.*), and an elongated distal portion, which is rolled

on itself longitudinally to form a tube. This distal portion probably represents the endopodite (*end.*). The two basal portions fuse in the middle line, thus forming a tunnel-like structure extending backward below the second somite. Below the fused basal portions of the first pleopods arise the *second pair* of appendages (Pl. II, fig. 15). Each consists of two parts—a horizontal rod (*prot.*) projecting posteriorly, and a vertical rod (*end.*) attached to the posterior end of the first portion. The vertical rod is divided into two parts by a transverse groove. The horizontal rod probably represents the protopodite, and the vertical portion is the endopodite. There is no trace of an exopodite on any of the male pleopods.

The vertical rod-like portion of the second pleopod fits into the tube of the first pleopod.

## ENDOPHRAGMAL SKELETON

(Pl. III, fig. 18, Text figs. 4, 5, 6, 7).

The post-oral region of the cephalothorax has an extremely complex system of internal plates, known as the endophragmal skeleton. Essentially this system may be said to consist of a number of inwardly-projecting plates arranged transversely so as to divide up the interior of the cephalothorax into a series of irregular compartments. Each partition, or arthrophragm, arises at the junction of two somites, and is formed by an infolding of the sternal and epimeral exoskeleton between these somites. Thus, each plate of the endophragmal skeleton is double, and is composed of two flattened plates of exoskeleton which are closely applied together.

The primary function of the endophragmal system is

to afford attachment for the muscles of the proximal region of the appendages in this region of the body. It is also useful in supporting and protecting certain portions of the viscera.

Although at first sight the arthrophragms of the first five post-oral cephalothoracic somites differ in a marked degree from those of the posterior thoracic region, it will be shown that all are built on the same plan.

### Description of a Typical Arthrophragm (Text fig. 4).

The fourth thoracic arthrophragm (between the fourth and fifth thoracic somites) may be taken as a type. It is a vertical partition extending inwards at each side from the line of junction of the fourth and fifth thoracic epimera. The portion of the partition in contact with the thoracic sternum arises between the fourth and fifth thoracic sterna. Thus we may distinguish between two kinds of plates, viz., those growing inwards from the epimera—the **endopleurites** (Pl. III, fig. 18, *ep.*, also Text figs. 4, 5, 7), and those arising from the inner side of the sternum the **endosternites.** Each arthrophragm consists, therefore, of an outer endopleurite and an inner endosternite at each side of the middle line. The two endosternites in the arthrophragm under discussion are separated from each other in the middle line by the *median plate* (fig. 18, *med. p.*), which is an ingrowth from the median suture present on the last four thoracic sterna. The plates of which the arthrophragm is composed are sometimes known as the "apodemata."

The E n d o s t e r n i t e is irregular in shape and has five principal borders.

The *median border* is vertical, and is the part of the endosternite in contact with the median plate.

The *sternal border* (Text fig. 4, *Sb. s.*) is in contact with the sternum, and forms the ventral boundary of the endosternite.

The *articular border* (*Ab. s.*) passes upwards and outwards, and is equal in length to the sternal border. It is connected with the arthrodial membrane in contact with the coxopodites of the fourth and fifth thoracic appendages.

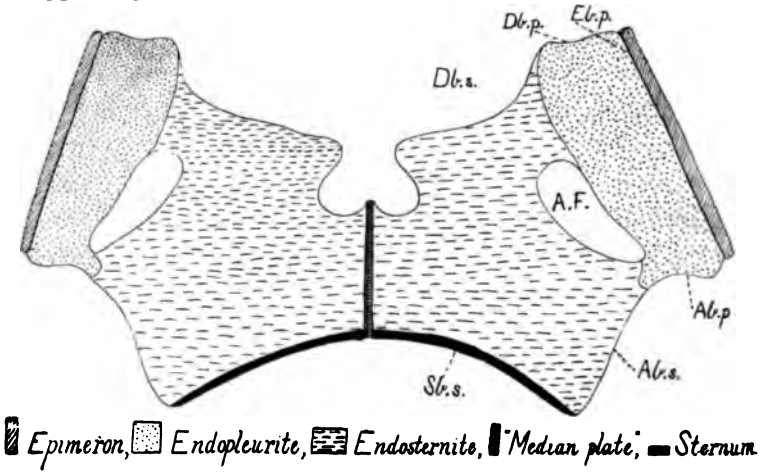



FIG. 4.—Diagram of a typical arthrophragm.

*Db.p.* = dorsal border of the endopleurite.
*Db.s.* = dorsal border of the endosternite.
*Eb.p.* = epimeral border of the endopleurite.
*Ab.p.* = articular border of the endopleurite.
*Ab.s.* = articular border of the endosternite.
*Sb.s.* = sternal border of the endosternite.
*A.F.* = apodemal foramen.

The *outer border* passes inwards and upwards, and at its upper and lower ends fuses with the endopleurite. This fusion is interrupted in the middle region of the border by the large *apodemal foramen* (*A.F.*) which lies between the endosternite and endopleurite.

The inner part of the *dorsal border* (*Db. s.*) passes

upwards and outwards from the median line, describing almost a semi-circle. The upper edge of the semi-circle almost reaches the median line. Thus the inner portion of the dorsal border of each side surrounds an almost closed cavity, which corresponds to the "sternal canal" of the Macrura.

The Endopleurite is rectangular in shape, and its length is about twice as great as its width. Four borders may be distinguished.

The *inner border* is in contact with the outer border of the endosternite at its upper and lower ends. In the intermediate region it forms the outer boundary of the apodemal foramen.

The *articular border* (*Ab. p.*) is in contact with the upper part of the arthrodial membrane connecting the coxopodites of the fourth and fifth thoracic appendages.

The *epimeral border* (*Eb. p.*) is in contact with the fourth and fifth thoracic epimera.

The *dorsal border* (*Db. p.*) bounds the dorsal free end of the endopleurite

Above the apodemal foramen the endopleurite becomes fused on its posterior face with the following arthrophragm, and the anterior face of the arthrophragm under discussion becomes fused with the preceding endopleurite.

All the arthrophragms of the post-oral cephalo-thoracic region are built on the above plan, that is to say, each somite has one endosternite and one endopleurite at each side. But in some cases the homology is very much disguised.

The last five thoracic arthrophragms are very similar to the one described, but the anterior arthrophragms are extremely reduced. It is, therefore, advisable to describe the endophragmal skeleton in two parts.

(1) The last five thoracic arthrophragms, beginning in front and working backward (posterior thoracic).

(2) The two post-oral cephalic arthrophragms and the first three thoracic arthrophragms, beginning behind and working forward (anterior post-oral).

### (1) Posterior Thoracic Endophragmal System

(Pl. III, fig. 18, and text, fig. 5).

This consists of the arthrophragms of the last five thoracic somites

The *median plate* commences at the posterior end of the fourth thoracic sternum. At first it is extremely shallow, but as it proceeds posteriorly it increases in height. It is present in the last four thoracic somites.

As in other parts of the endophragmal system, the median plate is composed of two closely applied portions of the exoskeleton. In the fifth thoracic somite these two parts remain separate, and the cavity between them opens to the exterior at the posterior end of the fourth thoracic sternum.

Each endosternite is at right angles to that part of the sternum from which it arises, and similarly each endopleurite arises at right angles to the epimeron. If the sternum were horizontal throughout its entire length, and also if the epimeral wall at each side were vertical, the endophragmal system would be represented by a series of vertical partitions arranged one behind the other. This is the case in the Macrura. In the Brachyura, however, neither the sterna nor epimera follow this arrangement. The thoracic sternum is extremely convex antero-posteriorly and has an extreme upward tilt at its posterior end. The epimeral wall, instead of having a flat surface, is extremely convex on its outer face. The shape of the sternum and of the epimeral wall gives rise to much

complexity in the endophragmal system of the last five thoracic somites. The endosternite and the endopleurite of the same arthrophragm instead of being in the same plane, as in the Macrura, may be situated at a considerable angle to each other, so that it is difficult to believe that they belong to the same segment. The fifth endosternite is almost vertical, but the succeeding endosternites incline more and more forward until the last arthrophragm is practically horizontal.

The endopleurites of each arthrophragm become fused with the anterior face of the following arthrophragm, and thus we have each somite divided into four chambers. There is an outer chamber at each side lying between two consecutive endopleurites, and bounded on the outer side by the epimeron and on the inner side by the backward growth of the endopleurite. These chambers may be called the *Pleural muscle chambers* (Text fig. 6, *P.*).

There is also an inner chamber at each side, lying between two consecutive endosternites, and separated from one another by the median plate. We designate these the *Sternal muscle chambers* (Text fig. 6, *S.*).

These pleural and sternal muscle chambers contain the muscles which work the two basal segments of the appendages in this region.

The muscle chamber of the last walking leg is not divided into parts owing to the absence of a separate endopleurite in this somite. Therefore this last muscle chamber may be known as the *Pleuro-Sternal muscle chamber* (Text fig 6, *PS.*). Each of these chambers has an antero-lateral prolongation, which extends forward as far as the posterior face of the fourth thoracic arthrophragm.

The **fourth thoracic arthrophragm** (Text fig. 5, *A.*) arises between the fourth and fifth thoracic somites. This arthrophragm has already been described.

The **fifth thoracic arthrophragm** (Text fig. 5, *B.*) arises between the fifth and sixth thoracic somites. All the parts are very similar to those described in the fourth arthrophragm. The sternal border is slightly more

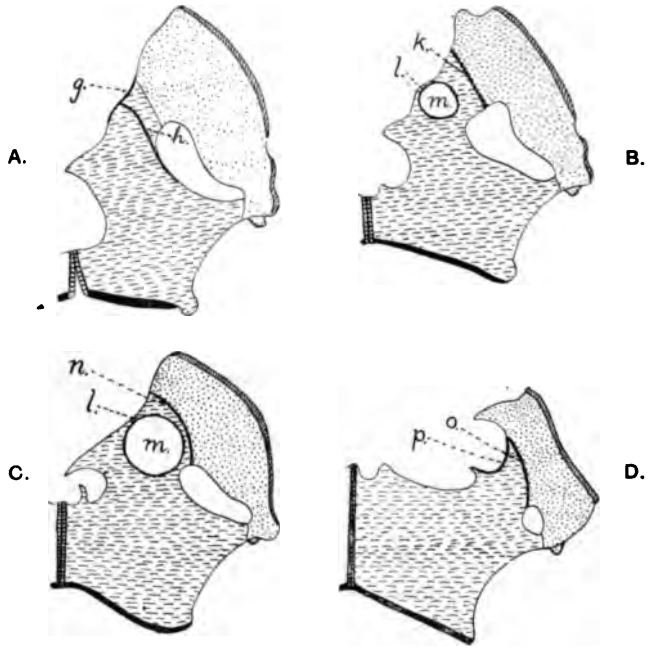



FIG. 5.—Anterior view of the left side of thoracic arthrophragms.

A. = 4th thoracic arthrophragm. B. = 5th thoracic arthrophragm.
C. = 6th thoracic arthrophragm. D. = 7th thoracic arthrophragm.
(The parts are shaded as in Fig. 4).

*g.* = line of fusion with the following arthrophragm.
*h.* = line of fusion with the 3rd thoracic endopleurite.
*k.* = line of fusion with the 4th thoracic endopleurite.
*l.* = line of fusion with posterior face of the preceding thoracic endosternite.
*m.* = antero-lateral extension of pleuro-sternal muscle chamber.
*n.* = line of fusion with the 5th thoracic endopleurite.
*o.* = line of fusion with the 6th thoracic endopleurite.
*p.* = line of fusion with the 6th thoracic endosternite.

arched. The apodemal foramen is not quite so large. There is an additional cavity left in the dorsal side of the endosternite at each side (*m.*) This is formed by the

anterior prolongation of the last pleuro-sternal muscle chamber.

The endosternite is almost vertical, but there is a slight forward tilt. The endopleurite is slightly concave on its anterior face, and its plane is slightly posterior to that of the endosternite. The border of the endosternite surrounding the sternal canal has a slight notch. Around the foramen of the pleuro-sternal muscle chamber the endosternite of this arthrophragm fuses in front with the fourth endosternite (*l.*) and posteriorly with the sixth endosternite. Similarly along the outer border of the endosternite, above the apodemal foramen, this arthrophragm is fused in front with the fourth endopleurite (*k*) and behind with the sixth endopleurite.

The **sixth thoracic arthrophragm** (Text fig. 5, *C.*) arises between the sixth and seventh thoracic somites.

The endosternite is convex on its anterior face, and its plane is inclined considerably forward. Its median border is longer than in the previous arthrophragms. The notch in the sternal canal is much more pronounced than in the fifth arthrophragm. The upper border of the sternal canal is bent posteriorly, and its inner tip becomes fused with the upper edge of the median plate in the last somite. The dorsal border is fused with the anterior (or dorsal) edge of the last arthrophragm. In this way the seventh endosternite is completely roofed over and cannot be seen clearly until the sixth endosternite is removed. As in the previous arthrophragm, there is a large foramen in the dorsal region of the endosternite through which the pleuro-sternal muscle chamber passes (*m.*).

The endopleurite is very similar to that of the fourth arthrophragm. At the junction of the endosternite and endopleurite this arthrophragm fuses in front with the fifth endopleurite (*n.*), and behind with the seventh endo-

pleurite. Also at the edge of the foramen bounding the pleuro-sternal muscle chamber this endosternite is fused in front to the fifth and behind to the seventh endosternite (*l.*).

The **seventh thoracic arthrophragm** (Text fig. 5, *D.*) lies between the seventh and eighth thoracic somites.

The endosternite is inclined at an angle of 50° to the vertical, the upper border being anterior. It is almost completely covered by the overhanging sixth endosternite. The median border is very deep and the sternal canal is very small. The dorsal border is almost level, and partly bounds the ventral side of the pleuro-sternal muscle chamber. The endosternite does not completely surround this chamber as in the two previous arthrophragms. The sternal border is inclined at a considerable angle to the horizontal. The apodemal foramen is small.

The plane of the endopleurite is almost at right angles to that of the endosternite. At the junction of the endosternite and endopleurite this arthrophragm fuses in front with the sixth endopleurite (*o.*), and where the endosternite borders the pleuro-sternal muscle chamber there is a fusion with the sixth endosternite (*p.*).

The **eighth thoracic arthrophragm** (Pl. III, fig. 18, *e. st.* 13) lies at the posterior end of the last thoracic somite. In this somite there is no separate epimeron. It is probably fused with the sternum. The arthrophragm, therefore, shows no division into endosternite and endopleurite. It may be accepted, however, that this arthrophragm represents the fused endosternite and endopleurite. It consists of two halves, which are separated in the median line by the posterior end of the median plate. This arthrophragm is practically horizontal, and was designated the "sella turcica" by Milne-Edwards. As already stated, the last arthrophragm fuses in front

with the dorsal border of the sixth endosternite. Between this arthrophragm and the seventh endopleurite there is a large foramen.

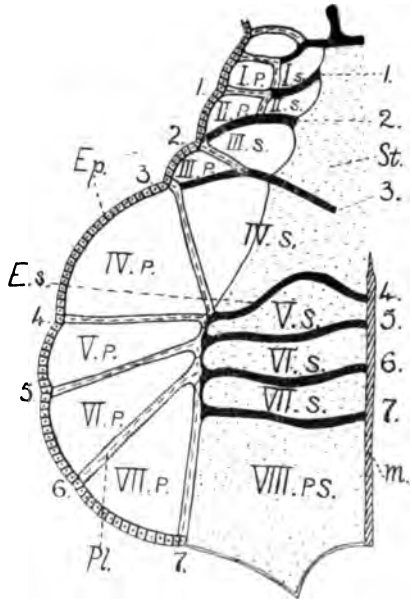



FIG. 6—Diagrammatic plan of the endophragmal system to show the muscle chambers. (The corresponding parts are shaded similarly throughout).

1—7 = thoracic arthrophragms 1 to 7.
*I.P.* — *VII.P.* = pleural muscle chambers of thoracic somites 1—7.
*I.S.* — *VII.S.* = sternal muscle chambers of thoracic somites 1—7.
*VIII.P.S.* = pleuro-sternal muscle chambers of last thoracic somite.
*Ep.* = epimeron.
*E.s.* = endosternite.
*Pl.* = endopleurite.
*St.* = sternum.
*m.* = median plate.

(2) ANTERIOR POST-ORAL ENDOPHRAGMAL SYSTEM

(Text fig. 7).

This consists of the last three thoracic and the two post-oral cephalic arthrophragms.

The nature of the epimera and sterna in this region naturally decides the form and extent of the corresponding arthrophragms.

The apparently great differences between the endophragmal system of this region and that of the posterior thoracic somites is due to three main causes.

(1) There is no median plate. This only begins at the level of the fourth thoracic arthrophragm.

(2) The post-oral sterna anterior to the fourth thoracic arthrophragm are all fused together. Consequently there can be no broad plate-like endosternites formed as in growths between the somites. The small endosternite present in each somite of this region is rod-like, and represents merely the articular border of the typical endosternite. (The third thoracic endosternite has the form of a fairly broad and deep plate, and is therefore an exception to this rule.)

(3) The epimera in front of the second thoracic arthrophragm are fused together, so that the endopleurite in these somites are extremely reduced and represent only the articular border of the typical endopleurite.

Here, as in the posterior thoracic region, each endopleurite gives off a posterior out-growth, which fuses with the following arthrophragm. So that pleural muscle chambers and sternal muscle chambers may be made out, but owing to the rod-like nature of their constituent parts, they have a very different appearance from the muscle chambers of the posterior somites of the thorax (see Text fig. 6, also Pl. III, fig. 18).

The **third thoracic arthrophragm** (Text fig. 7, *E.*) arises between the third and fourth thoracic somites.

Each endosternite (Pl. III, fig. 18, *e.st.*8) differs from that of the typical arthrophragm described above. It arises merely from the outer edge of the sternum, so that the two endosternites are separated from each other by the entire width of the sternum in this region. The endosternite is a broad and deep plate facing downwards and backwards. The dorsal and inner corner is prolonged inwards and backwards and almost meets the similar part from the other side.

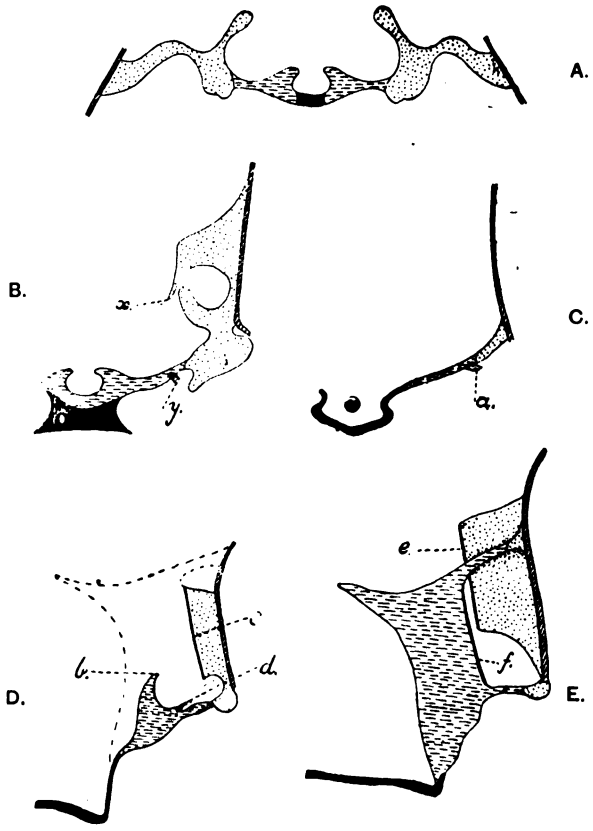



FIG. 7.

*A.* = anterior view of 1st post-oral cephalic arthrophragm.
*B.*—*E.* = anterior views of the left side of the following arthrophragm.
*B.* = 2nd post-oral cephalic arthrophragm.
*C.* = 1st thoracic arthrophragm.
*D.* = 2nd thoracic arthrophragm. *E.* = 3rd thoracic arthrophragm.
(The parts are shaded as in Fig. 4).
*a.* = junction of 2nd cephalic endopleurite with 1st thoracic endosternite.
*b.* = point of fusion between 2nd thoracic endosternite and 2nd cephalic endopleurite.
*c.* = line of fusion between 2nd thoracic endopleurite and 3rd thoracic endosternite.
*d.* = point of fusion with the 1st thoracic endopleurite.
*e.* = line of fusion between 3rd thoracic endopleurite and the 4th thoracic endosternite.
*f.* = line of fusion between 3rd thoracic endosternite and the 2nd thoracic endopleurite.
*x.* = point of fusion between the 2nd cephalic endopleurite and the 2nd thoracic endosternite.
*y.* = point of fusion with 1st cephalic endopleurite.
(The dotted line in Fig. D represents the 3rd thoracic endosternite.)

On its anterior face the endosternite is connected with the narrow plate-like second thoracic endopleurite (*f.*). Near the point of junction of these two plates the dorsal and articular borders are prolonged backwards as rod-shaped pieces, each of which comes into contact with anterior rod-like outgrowths from the corresponding borders of the third thoracic endopleurite.

The endopleurite arises betwen the third and fourth epimera. It gives off two short anterior rod-like prolongations from the dorsal and articular borders which fuse with the rod-like extensions of the endosternite mentioned above. The main part of the endopleurite, however, consists of a broad plate, which passes backwards and fuses with the fourth thoracic arthrophragm (*e.*).

**Second thoracic arthrophragm** (Text fig. 7, *D.*). The endosternite is much more reduced than that of the third thoracic arthrophragm. It arises from the upturned edge of the sternum in this somite, and has a very irregular shape. Its inner portion passes upwards, and fuses with a narrow membranous process projecting downwards from the last cephalic endopleurite (*b.*).

The articular border is prolonged outwards as a rod-like process, which fuses with the extremely small articular border of the endopleurite of the same arthrophragm. About half way along the articular border the endosternite fuses with a posterior rod-like extension of the first thoracic endopleurite (*d.*).

The endopleurite of this arthrophragm is a deep narrow plate arising at the junction of the second and third thoracic epimera. From its lower end it sends forward a short process which fuses with the outer part of the endosternite. The main part of the endopleurite passes backwards and becomes fused with the third thoracic endosternite (*C.*), as described above.

**First thoracic arthrophragm** (Text fig. 7, *C.*). The endosternite arises from the upturned edge of the sternum. It consists of a simple rod which passes backwards, upwards and outwards parallel to the articular border of the second thoracic endosternite. It fuses with the endopleurite of the same arthrophragm, but immediately before doing so it comes into contact, on its anterior side, with a posterior prolongation from the last cephalic endopleurite (*a.*).

The epimera of the first and second thoracic somites are fused together, and the endopleurite of this arthrophragm arises from the ventral edge of the fused epimera immediately in front of the origin of the second thoracic endopleurite. It is rod-like, and passes forwards and inwards in precisely the same plane as the first thoracic endosternite, with which it fuses. Near its fusion with the latter, the endopleurite gives rise to a posterior process which fuses with the second thoracic endosternite.

**Last cephalic arthrophragm** (Text fig. 7, *B.*). The endosternites of the two post-oral cephalic arthrophragms are fused together, but there is a distinct longitudinal suture present, which assists in the identification of the two parts.* The fused endosternites pass outwards and backwards parallel to the first thoracic endosternite. After a short distance the last cephalic endosternite becomes distinct from the anterior endosternite, and at the point of separation a prolongation from the first cephalic endopleurite fuses with the endosternites (*y.*). From this point the posterior endosternite passes outwards and fuses with the lower border of the last cephalic endopleurite.

The last cephalic endopleurite is an irregular

* There is also a well-marked groove separating the sternum of these two cephalic somites.

membranous plate divided into a dorsal and a ventral portion. The dorsal portion has on its inner side a downwardly projecting process which fuses with the upper part of the second thoracic endosternite (*x.*) as described above. The ventral portion of the endopleurite has an upper crescent-shaped region and a lower part which fuses with the endosternite.

From the posterior side of the lower portion of the endopleurite is given off a rod-like process which fuses with the first thoracic endosternite.

**First post-oral cephalic arthrophragm** (Text fig. 7, *A.*). In addition to the portion fused with the last cephalic endosternite, the endosternite of the above arthrophragm has an anterior process at each side which form the skeleton of the metastoma (Pl. III, fig. 18, *met.*) or posterior lip of the mouth.

The endopleurite arises from the soft membranous epimeron immediately behind the insertion of the external abductor muscle of the mandible. It passes backwards and gives rise to a small upwardly directed process, and afterwards becomes joined to the fused endosternites.

### Integument (Text fig. 8).

The crab is covered by a continuous chitinous exoskeleton, which serves partly as a protective covering and also as a means of attachment for the muscles. The main portion of this exoskeleton is strongly calcified. Between the movable somites of the abdomen, however, and also between the articulating segments of the appendages, the exoskeleton remains uncalcified in order to allow of free movement, and has the appearance of a thin chitinous membrane, known as the "arthrodial membrane."

The exoskeleton of the ventral region of the abdomen

is but feebly calcified. The outer walls, the floor and roof of the branchial chamber and the roof of the pre-branchial chamber are also extremely thin and membranous. The chitinous linings of the fore-gut and hind-gut, which are continuous with the exoskeleton, are uncalcified, except in those regions of the fore-gut where the ossicles are present. The gills, also, are covered by an extremely fine chitinous layer.

The integument of the crab consists of an epidermis, below which lies the dermis. On the outer side of the epidermis is a chitinous layer, the thickness of which differs considerably in various parts of the body. This outer chitinous layer is a product of the epidermis, and constitutes the exoskeleton already referred to. The chitinous layer may be impregnated with calcareous salts.

The **epidermis** [Chitogenous epithelium, Vitzou*] (Text fig. 8, *e.*) consists of a single row of columnar cells resting upon a *basement membrane* (*f.*). These cells differ in their appearance in various parts of the body, and also show marked changes during the interval between one act of ecdysis and the next. In the dorsal integument of the hard crab, for example, the cells of the epidermis are only moderately columnar, but in the oesophagus of the same animal the cells are extremely elongated. In the soft crabs the cells are of much greater length comparatively than in the hard crabs.

In some regions where we have two parts of the integument coming close together, such as at the edge of the carapace and also the gill lamellae, the cells of the epidermis sometimes become extremely elongated and pass across the dermis to fuse with similar cells from the

* Vitzou, A. N. "Recherches sur la structure et la formation des téguments chez les Crustacés Décapodes." *Arch. de Zoologie expér. et gén.*, T. X. [1882], p. 451.

epidermis of the opposite side. Vitzou has termed such cells " colonnades de soutien."

The cells of the epidermis are also elongated at the point where the muscle fibres arise.

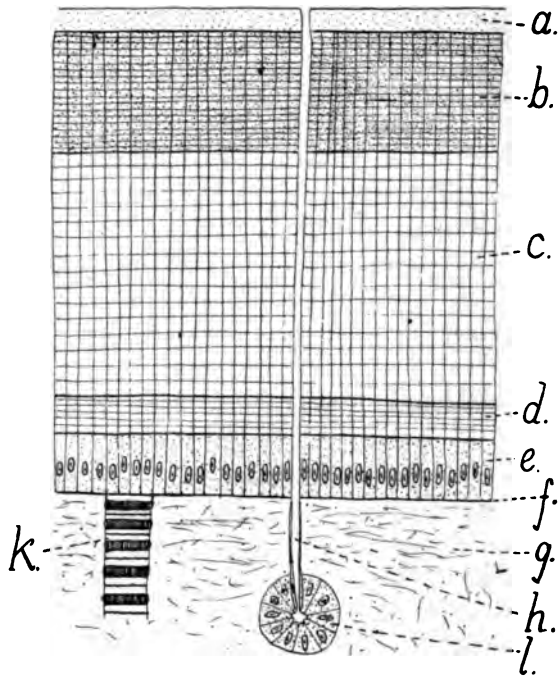



FIG. 8.—Diagrammatic section through the integument of a hard crab.

*a.* = cuticle.
*b.* = pigmented layer.
*c.* = calcified layer.
*d* = non-calcified layer.
*e.* = epidermis.
*f.* = basement membrane.
*g.* = dermis.
*h.* = duct of the cutaneous gland.
*k.* = muscle attached to the basement membrane.
*l.* = cutaneous gland.

The **dermis** (*g.*) lies below the basement membrane, and varies in thickness. It consists mainly of a network of connective tissue fibres and scattered cells. There is a layer of pigment cells close to the basement membrane.

As pointed out by Cuénot,* there are two kinds of cells present in the connective tissue which contain reserve material. These are the "cellules de Leydig" and the "cellules protéiques." The former contain glycogen, and are present in great numbers, especially when the period of ecdysis approaches. The latter are also present in great abundance, and contain proteid material.

The cutaneous glands are also embedded in the dermis. The muscle fibres stretch across the dermis, and are attached to the inner side of the basement membrane. The muscles when dissected appear to be attached to the exoskeleton, but an examination of sections reveals the fact that they do not extend farther than the basement membrane.

The **chitinous layer** of the integument is situated on the outer side of the epidermis, and consists of several layers. Commencing from the outside, these are as follows:--

(1) The *cuticle* (Text fig. 8, *a.*) is an extremely thin structureless layer covering the whole of the chitinous exoskeleton. Its continuity is interrupted at intervals where the ducts of the cutaneous glands open to the exterior. From the cuticle there arise numerous small papillae, which are only seen when examined under the microscope. These must not be confused with the setae, which are visible to the naked eye and which have an entirely different structure (see below).

(2) The *pigmented layer* (*b.*) is a moderately-thick layer containing pigment. In the hard parts of the exoskeleton this layer is calcified. It has a laminated structure, and the numerous layers of which this portion of the exoskeleton is composed are parallel to the surface.

(3) The *calcified layer* (*c.*) is the broadest layer of all

* Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, T. XIII, p. 245.

in the fully-formed exoskeleton. It is colourless and richly impregnated with calcareous salts. Like the previous layer, it exhibits striations parallel to the surface, but the laminae are generally broader than in the pigmented layer. It is to this layer that the great thickness and hardness of the shell in a hard crab are due, as new laminae are constantly being added to this region until the exoskeleton attains its maximum thickness.

(4) The *non-calcified layer* (*d.*) is a very thin layer composed of delicate laminae parallel to the surface. This layer remains in a very soft condition, and is not formed until the calcified layer has attained its maximum width.

Vertical sections through the integument reveal the fact that there are striations in the chitin at right angles to the surface, as well as the horizontal lamellae already referred to. Also, as Vitzou has pointed out, in horizontal sections the chitinous integument is divided up into small hexagonal areas, and in each of these areas small pores are present. Vitzou determined that these areas were of the same size and shape as the horizontal sections through the cells of the epidermis. He concluded, therefore, that the exoskeleton is composed of innumerable hexagonal prisms packed side by side, having their long axes at right angles to the surface of the body. Furthermore, each of these chitinous prisms is in contact with the outer end of an epidermal cell. So that for every cell of the epidermis there is a corresponding prism forming a unit of the chitinous exoskeleton. Such an explanation accounts for the presence of the vertical striations in vertical sections, and for the polygonal areas in the horizontal sections. The small pores in the middle of these areas are due to the presence of numerous fine canals traversing each prism from the epidermis to the exterior.

## Mode of Formation of the Exoskeleton.

Originally the exoskeleton was believed to be produced by a secretion from the cells of the epidermis. Vitzou, however, claimed that the process is effected in a different manner. According to him the new shell is produced in the following way. The contents of each epidermal cell becomes modified at the outer margin. This outer part becomes cut off from the rest of the cell. Thus at this stage the epidermis is covered by a thin layer, which, however is not one homogeneous whole, but is divided up into numerous polygonal areas, each area corresponding in shape and position to an epidermal cell. The process is repeated; the outer part of each cell is again cut off, and at this stage we have a two-layered polygonal cylinder above each cell. This process is repeated until we have built up over each cell a multilayered cylinder. Since the cells of the epidermis lie close together, the chitinous cylinders are also tightly packed and form what appears to be a continuous exoskeleton. The striations parallel to the surface of the integument represent the successive lines of growth. Thus, according to Vitzou, the process of formation of the chitinous integument consists in the successive thickening of the outer walls of the epidermal cells.

## Setae.

These are long hair-like processes which project from the exoskeleton in various regions of the body. In sections each seta is seen to arise from the region of the epidermis as a narrow tube enclosing a cavity. This tube passes through the chitinous layers and projects from the exterior as a long narrow process. Its walls are cuticular and are continuous with the thin structureless cuticle

covering the chitinous integument. So that wherever a seta arises the continuity of the thick exoskeleton is broken in order to allow this tube-like prolongation to reach the exterior. The contents of the setae are protoplasmic and are connected with the epidermis. In some regions of the body the setae have nerve fibres passing to their interior. These are the *sensory setae*, of which there are several kinds (see section on Sense Organs). The setae may be simple prolongations, or they may consist of a central axis, from which arise off-shoots. In the latter case the cavity of the central axis is not continued into the lateral out-growths. In addition to the setae described above, there are small papillae on the surface of the shell, which are merely thickenings of the cuticle and do not contain a cavity. Vitzou states that in Portunus these cuticular processes are comparatively long. In Cancer, however, they are extremely small, and can only be detected under the microscope. Vitzou affirms that the long "setae," present in the walls of the fore-gut, have no central cavity, and are probably merely extremely large cuticular prolongations and not true setae. These "setae" in the fore-gut act as strainers. Where the sub-branchial region of the carapace is closely applied to the bases of the thoracic legs there is a rich growth of setae. These probably assist in preventing the water from entering the branchial chamber at the base of the thoracic legs.

The inhalent branchial opening is also well guarded by long setae, both on the flabellum of the third maxillipede and on the anterior border of the coxopodite of the chela. The setae on the endopodites of the pleopods in the female are used for the attachment of the eggs.

Cutaneous (or tegumentary) glands.

Scattered throughout the connective tissue, near the basement membrane, are globular masses of cells, each cellular clump being connected with the exterior by a fine duct. These are the cutaneous glands. Each cell of the globular mass is in contact with a small cavity on its inner side. This central cavity of the glandular mass receives the secretion from the various cells. The cavity is connected with the duct, and thus the glandular secretion is enabled to pass to the exterior. The duct is lined by a fine protoplasmic wall. The wall of the duct probably represents a single cell, in which case the cavity of the duct is intracellular. The gland cells and the duct cell are all modified epidermal cells.

The cutaneous glands are scattered throughout the integument, and in some regions are extraordinarily abundant. The glands present in the mandibles and in the walls of the oesophagus, and also those in the hind-gut, have a similar structure to the ordinary glands on the surface of the body. They are, in fact, modified cutaneous tegumentary glands.

Immediately in front of the mouth there is a compact mass of cutaneous glands at each side, which open on the surface of the epistoma. These glands have the structure of the typical cutaneous glands, but are extremely large. They are about four times as large as those present in the walls of the oesophagus (see section on Alimentary Canal). Similar glands are found also in the metastoma, packed very closely together. Herrick* has also observed them in the same regions in the lobster. (See fig. 60.)

In the floor of the branchial chamber there is a well-defined transverse ridge lying in front of the inhalent

* Herrick. "The American Lobster." *Bull. U.S. Fish Com.*, Vol. XV., 1895.

branchial aperture. The epidermis in this region presents a very interesting condition, and there appear to be numerous modified cutaneous glands.

There are also great numbers of cutaneous glands present on the endopodites of all the maxillipedes.

On the endopodites of the pleopods of the female there are closely-packed tegumentary glands. According to Herrick, these secrete the cement which attaches the eggs to the endopodites of the abdominal appendages.

The function of the various tegumentary glands in various parts of the body is not clearly known. Lang* states that some have an excretory function. There is little doubt that the functions of these glands differ in various regions of the body. Those, for example, on the pleopods are extremely specialised. It is not inconceivable that the glands in the integument of the epistoma and metastoma may produce a secretion which is poured on the food as it enters the mouth.

The glands in the walls of the oesophagus are probably salivary glands. Herrick thinks that this explanation of their function no longer holds good, since glands of similar structure have been found in the walls of the hind-gut. This argument, however, does not carry much weight, if we recognise that *all* the tegumentary glands (both on the surface and in the walls of the alimentary canal) have the same essential structure, and yet are capable of performing different functions in various regions of the body.

## Ecdysis.

The epidermis of all Arthropods is covered by a continuous layer of chitinous integument, which may become calcified in certain regions. This outer integu-

* Lang. *Text-book of Comparative Anatomy*, Part I.

ment is continuous with the chitinous lining of the fore-gut and hind-gut. The body, therefore, may be said to be enclosed in an inflexible coat, which prevents the tissues from expanding. The growth of the animal cannot be gradual, but can only take place when the animal breaks through the stiff outer covering. Immediately after exuviation, the animal, which is then only covered by an extremely thin flexible membrane, will increase in size. This process of casting, or **ecdysis,** is characteristic of all Arthropods. Ecdysis takes place periodically, and growth can only take place while the animal is in a " soft " condition.

In Cancer, when ecdysis is about to take place, the carapace opens along the pleural groove at each side. These two longitudinal splits become connected posteriorly with a transverse opening, which makes its appearance between the posterior border of the carapace and the tergum of the first abdominal somite. Thus the tergal region of the carapace is free from the remainder of the exoskeleton, except along a line marking the posterior boundary of the first cephalic sternum. The carapace, therefore, acts like a lid of a box, and is hinged anteriorly. The first part of the body to be withdrawn from the old shell is the abdomen, which is followed by the various legs. When all the parts are completely free the crab emerges from beneath the hinged carapace.

On the dorsal sides of the basi-ischium and meros of the chela there are faint grooves (Pl. II, fig. 12, *abs.*). These are the " lines of absorption," and at the time of ecdysis the exoskeleton of the chela loses its calcification at these points. In this way the withdrawal of the large claw is effected, as it would be extremely difficult for the chela to be withdrawn if the integument at the base of the limb remained hard.

As pointed out by Vitzou,* the method of ecdysis in the Macrura differs from that found in the Brachyura, because in the latter the abdomen is withdrawn first. In the Macrura the thorax is first withdrawn, and the abdomen leaves the old shell last.

The tissues of the animal become greatly changed immediately before ecdysis. The blood increases enormously in volume, and Witten† suggested that the increase is due to the absorption of water by means of the digestive gland. He presumed that this excess of blood plasma produced the internal pressure necessary for ecdysis and growth. The muscles become very soft and semi-fluid, and the fibres lose their well-defined outlines and cross-striations.

The digestive gland probably increases in size during ecdysis. The fat cells are stocked with glycogen, the ferment cells are much bigger, and the colour of the ferment vesicle is of a deep brown colour, thus giving the digestive gland a deeper colour at this period. The reproductive organs are generally in an immature condition at the time of ecdysis.

Immediately before and after ecdysis the crabs are unfit for food. They are "watery" and have a bitter taste. Reference is made in the Economic section to the "Granny" crabs, which are considered by the fishermen to be diseased crabs. I have reason to believe that they are merely crabs preparing for ecdysis.

One of the most interesting changes which accompany ecdysis is probably the formation of the new integument, as a result of the extreme activity of the epidermal cells. This new exoskeleton is already formed when the hard shell is discarded.

* Vitzou. *Arch. zool. exp. et gén.*, T. X, 1882.

† *Report on the Scientific Investigations, Northumberland Sea-Fisheries Committee*, 1903.

Before ecdysis the cells of the epidermis become greatly elongated, and in the underlying dermis the cells of Leydig, which are rich in glycogen, become extremely numerous. The supply of reserve food material in these cells is evidently of the utmost importance at a time when growth and regeneration of the tissues is taking place. At the time when the crab is preparing to cast, a new chitinous layer is formed by the epidermis. This new layer is separated from the old shell by a gelatinous fluid. The chitinous layer, which is the first appearance of the new exoskeleton, consists of two parts—an outer structureless cuticular layer, and an inner chitinous layer containing pigment. This inner layer represents the pigmented layer. The calcified and non-calcified layers are not produced until after ecdysis. The calcified layer grows throughout the greater part of the period until the next ecdysis, and it is to this layer that the hardness and increasing thickness of the shell is due.

Vitzou's theory explaining the method of formation of the exoskeleton has been described above (see section on Integument).

The frequency of casting and other problems connected with ecdysis are discussed below in the section on Economics.

### Autotomy and Regeneration of Limbs.

One of the most interesting and characteristic features in the natural history of the crab is the power the animal possesses of throwing off injured limbs (**autotomy**) and of forming new limbs to replace the old (**regeneration**).

The processes associated with these phenomena may be briefly stated as follows:-

If the distal portion of one of the pereiopods be

seriously injured, the crab immediately throws off part of the limb. The whole limb is not sacrificed. The self-amputation always takes place along the thin groove present on the basi-ischium representing the line of separation between the basipodite and ischiopodite. This groove, therefore, may be said to surround the **fracture plane** (Pl. II, fig. 12, *f.p.*).

When autotomy has been effected, the fracture plane is seen to be covered by a thin membrane, or **diaphragm**, which is perforated, slightly below the centre, by a small foramen. The blood flows out through this small opening, but soon coagulates, forming a clot over the mouth of the foramen and also on the outer surface of the diaphragm.

The diaphragm with its outer coating of coagulated blood assumes a dark brown colour in a few days, and ultimately becomes quite black. This black coating is worn away in course of time, and reveals a thin membrane extending across the stump.

Beneath the membrane a small papilla makes its appearance, and marks the commencement of the regeneration of the limb.*

## Conditions necessary for Autotomy.

The successful performance of self-amputation in Cancer depends upon several conditions, of which the most important are discussed below.

1. *The crab must be healthy.*

This is a most important factor. Animals which are in a diseased or weak condition, or which have been kept out of water for a considerable time, and in which, as a

* According to Williamson, the regeneration only takes place when the crab is preparing for ecdysis. The limb does not attain its full size at the first moult after regeneration. Two or three moulting processes must take place before the limb attains its normal size.

consequence, the nerve responses are feeble, do not perform autotomy very readily.

2. *The nerve of the limb must be sufficiently stimulated.*

This appears to be a self-evident proposition. Whatever may be the cause of autotomy, and whatever may be the reason of this complex phenomenon, it is without doubt the result of nervous stimulation. But the question as to what is a " sufficient " stimulation cannot be disposed of so easily (see below under the general discussion on Autotomy).

3. *The thoracic nerve mass must remain intact.*

We are indebted to Fredericq* for his investigations on the physiological processes involved in autotomy. He has proved that the latter is the result of a reflex, and that the thoracic ganglion belonging to the appendage is the centre of this reflex. The brain is the seat of voluntary and co-ordinated movement in Cancer, and if the brain be removed autotomy will still take place. If, on the other hand, the thoracic nerve mass be removed or destroyed, self-amputation cannot proceed. The afferent nerve fibres which are stimulated as the result of injury to the limb are connected with the ganglion cells of the thoracic nerve mass, and from these the efferent fibres pass to the extensor muscle of the basi-ischium. This muscle is the one concerned in the autotomy, and thus we are provided with a fourth condition.

4. *The integrity of the extensor muscle of the basi-ischium must be maintained.*

The first movement after the limb has been injured is the extension of the basi-ischium; i.e., it moves in a dorsal direction. This movement continues until the

* Fredericq, L. " Nouvelles recherches sur l'autotomie chez le crabe." *Archives de Biologie*, T. XII, 1892.

distal portion of the limb comes into contact with the carapace or with some other fixed object, when the limb breaks at the fracture plane. That this upward movement, or extension, of the basi-ischium is necessary for autotomy may be proved by cutting the extensor muscle (or muscles), and then injuring the limb. No self-amputation will then take place. If the flexor muscle be cut, and the extensor remain uninjured, autotomy will proceed.

5. *The distal portion of the limb must come into contact with some point of resistance.*

This condition has been emphasised above. As soon as that part of the limb on the distal side of the fracture plane comes into contact with some point of resistance (e.g., the carapace) the upward movement of this portion is stopped. The proximal portion of the basi-ischium, however, still continues to move upwards under the influence of the extensor muscle. Thus there are two forces acting on the fused basi-ischium—a force at the proximal end tending to move the segment upward, and a force at the distal extremity preventing this upward movement. A great strain is produced on the basi-ischium and it snaps at its weakest point, which is the fracture plane.

6. *The stimulation to produce autotomy must be applied between the fracture plane and the distal end of the propodite.*

The nerve does not pass into the dactylopodite, so that if the latter segment be wounded the nerve will not be stimulated. It is equally futile if the limb be damaged on the proximal side of the fracture plane.

Amongst the Brachyura two kinds of autotomy have been recognised.

(1) If the crab is captured by means of one of its limbs it will throw off the limb in order to escape from its enemy ("evasive autotomy").

It is evident that all Decapods do not act similarly under such conditions. It does not appear to be the case in Cancer or Carcinus. Fredericq's researches led him to believe that crabs did not throw off legs in order to escape from enemies, but his experiments were confined to a few species. Taking all the evidence available, it would appear that autotomy does take place under the above conditions in some crabs, such as the Maiidae and the Grapsidae.

(2) If one of the legs of a crab be severely wounded, the limb will be thrown off. This probably occurs without exception in the Brachyura.

It is well to remember that in both cases we are probably dealing with essentially similar physiological conditions. In both cases the autotomy is produced as the result of the stimulation of the nerve of the leg, and the difference appears rather to be one of degree than of kind. In both the above cases the autotomy is produced as the result of a reflex, and the seat of this reflex is in the ganglion of the somite to which the autotomised leg belongs.

Quite recently, Piéron* has concluded that there is still another kind of autotomy which is purely voluntary, and will not take place after the commissures connecting the cerebral ganglia with the thoracic mass have been cut. One of his experiments with Grapsus was as follows:—A leg of the crab was tied to a stake within view of a

* Piéron, H. *C.R. Soc. Biol.*, 11th May, 1907. *Ibid.*, T. LXIII (1907), Nos. 33 and 34.

sheltered crevice in the rocks. The crab discarded the imprisoned limb as a conscious effort in order to reach the inviting shelter. This did not happen if the brain were destroyed or if the commissures were cut ("psychic autotomy").

It is difficult at the present juncture to accept Piéron's explanation, as Mlle. Drzewina† has also performed similar experiments with Grapsus, and has obtained entirely different results. But so far as Cancer is concerned, the "psychic autotomy" does not appear to be present.

It is not possible in the present state of our knowledge to arrive at a definite conclusion with regard to the full significance of the processes involved in autotomy. But whatever may have been the lines along which autotomy has been evolved, there is no doubt that one of its most important objects is the prevention of bleeding. If the arthrodial membrane between an appendage and the body be cut, the crab will probably bleed to death, and this appears to be one of the greatest dangers with which the animal has to contend. The limbs, on account of their position and size, are continually in danger of being torn or crushed. If the limb were seriously injured, and autotomy did not take place, the crab would bleed to death, because the wounded surface would probably be too large to allow coagulation to take place. This difficulty is surmounted by the limb being thrown off at the fracture plane, across which, as we have already seen, a membrane is stretched. This membrane is perforated by a small foramen through which pass the nerve and blood streams connecting the proximal and distal parts of the appendage. Over this foramen a clot may readily be formed, and thus the excessive bleeding may be prevented.

† Drzewina, A. *C.R. Soc. Biol.*, T. LXIII (1907), Nos. 33 and 34.

Histology. (Text fig. 9).

**Before autotomy.** A longitudinal section through the basi-ischium of a pereiopod in which autotomy has not been effected displays the following structure (9*A*.).

In the region of the fracture plane the exoskeleton is discontinuous, the plane of the discontinuity being at right angles to the longitudinal axis of the basi-ischium. The break is not always easily detected, as the two parts fit very closely together.

On the inner side of the exoskeleton is the normal layer of epidermis (*ep.*). At the plane of breaking the epidermis turns inward both at the distal extremity of the basipoditic region and also at the proximal end of the ischiopodite. These ingrowths extend as far as the central nerve and blood vessels, where the epidermal ingrowth of the basipodite (*i.*) becomes continuous with that of the ischiopodite (*o.*). In other words, across the plane of fracture the epidermis underlying the exoskeleton is not directly continuous, but becomes turned inward as far as the central nerve of the leg.

Thus there is a double diaphragm stretching across the leg in the fracture plane, and near the centre of this double membrane there is a small opening which permits of the passage of the nerve (*n.*) and blood vessels from one side to the other. The walls of this narrow opening are composed of a cellular membrane, which connects the proximal and the distal diaphragms.

**After autotomy.** The ischial portion of the exoskeleton is broken away at the fracture plane, and the underlying structures belonging to the ischium have also been torn away. These include the epidermis of the ischium and also the distal portion of the diaphragm. Stretching across the broken end of the stump (Text

fig. 9, *B.*) is a membrane representing the proximal portion of the double diaphragm (*i.*). Near the centre of this is a small foramen. In sections taken immediately after autotomy there is a layer of coagulated blood (*b.*) on the outer side of the diaphragm.

The torn edge of the diaphragm in contact with the foramen appears to grow over the latter. Thus, shortly after the autotomy has been effected, there is a continuous membrane or diaphragm covering the broken stump (9 *C.*). This membrane is composed of a single layer of epidermal cells, which is continuous with the epidermis underlying the exoskeleton of the basipodite. On the outer side of the membrane is a layer of coagulated blood. On the inner side of the ectoderm of this membrane, and lying close to it, there appears to be a continuous layer of connective tissue fibres. Miss Reed* describes also the presence of a dense mass of blood cells immediately beneath the membrane.

**Regenerative process.** Shortly after autotomy has taken place the cells of the diaphragm begin to degenerate (Text fig. 9, *D.*). Ultimately there is on the outside of the stump a layer of dead tissue, formed of an outer layer of coagulated blood, beneath which is the layer of degenerate epidermal cells. According to Miss Reed, there is also an inner layer of degenerate blood cells. The dead epidermal cells of the diaphragm become disconnected from the epidermis underlying the exoskeleton of the limb, and this epidermis grows inward beneath the dead outer layer. This takes place from all sides, and the in-growing cells meet in the centre and form a single

* Unfortunately I did not have access to Miss Reed's paper on the histological processes in connection with autotomy until after my own observations had been made. My results, in the main, however, bear out the conclusions arrived at in her paper (*Bryn Mawr College Monographs*, Reprint Series, Vol. V, 1905).

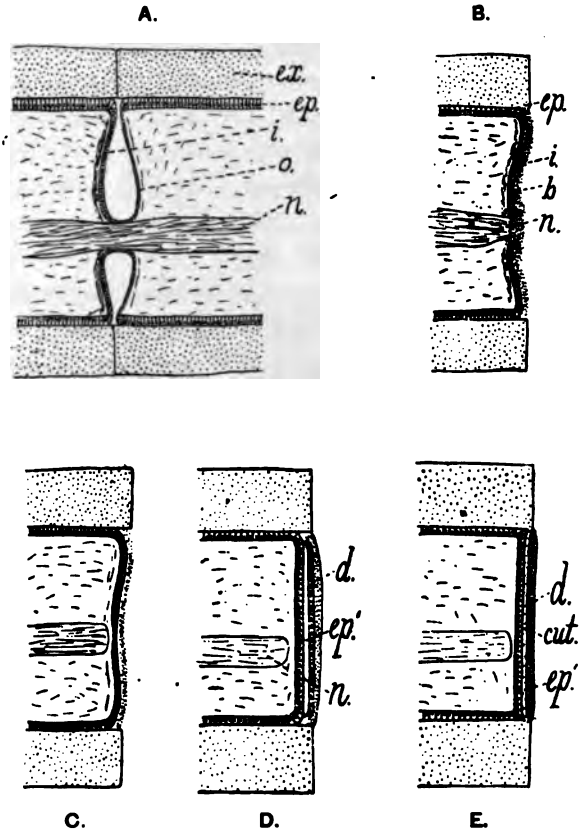



FIG. 9.—Diagrams to illustrate the histology of the structures in the fracture plane before and after autotomy. (In all the diagrams the proximal end of the limb is to the left).

*A.* = longitudinal section through basi-ischium before autotomy, showing the double nature of the diaphragm.

*B.* = longitudinal section through the basipodite immediately after autotomy. Showing the single diaphragm and the foramen.

*C.* = longitudinal section through the basipodite shortly after autotomy. The epidermis of the diaphragm has grown over the foramen.

*D.* = the degeneration of the diaphragm and the formation of a new layer of epidermis beneath.

*E.* = Formation of a thin cuticle (which is continuous with the exoskeleton) by the new epidermis.

*ep.* = epidermis.
*ex.* = exoskeleton.
*i.* = proximal part of diaphragm.
*o.* = distal part of diaphragm.
*ep'.* = new epidermis.
*n.* = nerve of the appendage.
*b.* = coagulated blood.
*d.* = degenerated diaphragm and blood tissue.
*cut.* = new cuticle formed by the new epidermis.

layer of cells beneath the outer dead layer. Eventually a thin layer of chitin is secreted on the outer side of these cells (Text fig. 9, *E.*), and this layer of chitin is continuous with the exoskeleton. The old membrane, which is now almost black, becomes worn off, and this new chitinous membrane is exposed.

The cells in the new layer of epidermis become extremely active, and increase in number internally. At first an undifferentiated mass of cells is formed beneath the membrane, but gradually differentiation takes place and the new parts of the limb are laid down in miniature. As they increase in size they grow outward, and form a small papilla on the stump.

## MUSCULAR SYSTEM.

(Pls. III, IV).

### Muscles of the Cephalothorax.

I. Eye. The ocular peduncle consists of two parts —an inner rod-like portion extending inwards as far as the middle line, and an outer swollen portion at the free end of which is the visual organ. The outer portion articulates with the inner, and is connected with the latter by means of a flexible membrane. The movement of the outer portion is effected by two small muscles—a ventral flexor and a dorsal extensor.

II. First antenna. The muscles are extremely small. The basal segment of the protopodite has a dorsal extensor and a ventral flexor. In their natural condition the second and third segments are flexed. In both cases the extensor is on the inner side and the flexor muscle is on the outer side.

III. Second antenna. The basal region of this appendage is fused with the carapace, and the muscles have degenerated. The operculum, which probably represents the coxopodite, is still freely movable, but its extensor and flexor muscles have now another function in connection with the raising and closing of the operculum. The whole question of the homology of the opercular muscles has been fully discussed by Marchal.* The flagellum has not much movement, and its muscles are very small.

IV. Mandible (fig. 31). There are two sets of muscles—the adductors for closing the mandibles and the abductors for opening the mandibles.

*External adductor muscle* (*e.a. md.*). Arises as a broad band from the anterior and outer portion of the subhepatic region of the carapace. It passes inwards and upwards, and is inserted on a long tendon attached to the outer part of the mandibular apophysis.

*Internal adductor muscle* (*i.a. md.*). Arises from the urogastric region of the carapace. It passes downwards and forwards as a short broad muscle, and is inserted on an extremely long narrow tendon attached to the posterior margin of the mandible.

*External abductor muscle* (*e.b. md.*). Arises from the posterior and inner corner of the hepatic region of the carapace. It passes directly downwards, and is inserted on a narrow tendon attached to the posterior side of the apophysis. This muscle is comparatively small.

*Internal abductor muscle* (*i.b. md.*). Arises from the top of the vertical rod-like portion of the first post-oral endopleurite. It passes outwards and forwards, and is attached to the outer part of the apophysis.

* Marchal. "Appareil excréteur des Crustacés Décapodes." *Archives Zool. exp. et gén.* (Ser. 2), T. X, 1892.

V. First maxilla (fig. 26). There are two extensors and two flexors.

*Flexors.* One outer (*o.e.m.*) and one inner (*i.e.m.*) muscle, which run together and arise from the outer portion of the protogastric region of the carapace. They pass directly downwards together, and when near the maxilla the two separate and are inserted on the outer and inner parts of the coxopodite respectively.

*Extensors.* One outer (*o.f.m.*) and one inner (*i.f.m.*) The tops of the two pillar-like portions of the first post-oral endopleurites are joined by a strand of tissue. Beneath the arch thus formed the two muscles arise near the middle line. They pass downwards and slightly inwards, diverging somewhat as they approach the appendage. They are inserted on the coxopodite at the same point as the corresponding flexor muscle.

VI. Second maxilla. There are two extensors and two flexors.

*Extensors.* The inner extensor arises from the posterior face of the first post-oral endopleurite. It is a short muscle which passes downwards and slightly outwards, and is inserted on the outer side of the coxopodite.

The outer extensor is a long narrow muscle. It arises from the epimeron of this somite just in front of the last cephalic endopleurite. It passes inwards and downwards across the anterior face of the flexors of the scaphognathite, and is inserted close to the small inner extensor.

The two *flexors* are small, and arise close together near to the origin of the outer extensor. They pass directly downwards, and are inserted near together on the inner side of the coxopodite.

The **Scaphognathite** (figs. 27, 28) has a complex movement, and the plane of motion is roughly at right angles to its long axis. There are two sets of muscles—extensors which pull the organ downwards, and flexors which draw it up again to its natural position. In the upward movement the scaphognathite does not remain flat, as when in a position of rest, but it becomes curved so that the upper side is concave. This is effected by a set of accessory muscles. The latter extend into the leaf-like portion of the scaphognathite, and do not stop at the edge of the organ, as do the other muscles.

All the flexors arise from the anterior face of the last cephalic endopleurite. Their names have been given according to the position of insertion on the scaphognathite. The flexors are inserted on the anterior wall of the base of the scaphognathite.

*Inner flexor* (*i. e. s.*) A long narrow muscle arising from the upper part of the endopleurite. It passes down the latter and, turning slightly inwards, it is inserted on the innermost part of the base of the scaphognathite. It has a small branch which arises from the side of the epimeron.

*Outer flexor* (*o. e. s.*) An extremely broad muscle, which arises immediately beneath the origin of the previous muscle and also on its inner side. It passes down the endopleurite parallel to the epimeron, and is inserted on the extreme outer edge of the base of the scaphognathite.

*Outer median flexor* (*o. m. e.*) A long and fairly broad muscle, arising from the extreme inner border of the endopleurite above the large foramen of the latter. It passes downwards and outwards across the front of the foramen, and is inserted on the base of the scaphognathite on the inner side of the previous muscle.

*Inner median flexor* (*i. m. f.*) A very short muscle arising from the endopleurite near the middle of the base of the foramen. It passes downwards below the other flexors and is inserted at the base of the scaphognathite on the outer side of the inner flexor.

The extensor muscles are situated beneath the flexors, so that it is necessary to cut away the latter in order to expose the extensors. There is one extensor corresponding to each flexor, and the insertion of each extensor is near to that of the corresponding flexor. All the extensors arise at the base of the anterior face of the last cephalic endopleurite. They are all short muscles, and are inserted on the posterior wall of the base of the scaphognathite.

*Inner extensor* (*i. f.*) Arises at the base of the endopleurite. It passes inwards and is inserted close to the inner flexor.

*Inner median extensor* (*i. m. f.*) It lies immediately below the inner median flexor, and above the three other extensors. It arises about the middle of the base of the endopleurite and passes downwards and forwards. Its insertion is close to that of the inner median flexor.

*Outer median extensor* (*o. m. f.*) Its origin is on the inner side of the previous muscle. It passes obliquely outwards and forward beneath the previous muscle, and is inserted close to the insertion of the outer median flexor.

*Outer extensor* (*o. f.*) A very short and broad muscle arising on the outer side of the origin of the inner median extensor. It passes outwards and downwards and is attached to the scaphognathite close to the insertion of the outer flexor.

The last two muscles have their insertions situated in the thickened bulb-like portion of the scaphognathite.

The accessory muscles are situated entirely within the scaphognathite itself. Their function is to bend the scaphognathite during the process of lifting up or extending the latter.

There are two muscles which arise close together on the inner side of the insertion of the inner flexor of the scaphognathite. They extend outwards into the middle and inner portions of the scaphognathite.

The *anterior accessory* (*a. acc.*) divides into two parts, each of which is attached to the anterior wall of the scaphognathite.

The *posterior accessory* (*p. acc.*) also divides into two parts. One division appears to be inserted on the posterior wall and the other on the anterior wall.

VII. First maxillipede (fig. 29). Only the extensor and flexor of the **Coxopodite** need be noted here.

The *extensor* (*e. C.*) arises on the epimeron of this somite. It passes downwards and inwards between the two flexors of the flabellum and behind the extensor of the latter (see below). It is inserted near the outer and posterior margin of the coxopodite.

The *flexor* (*f. C.*) arises at the upper side of the posterior face of the last cephalic endopleurite on the inner side of the point where the latter fuses with the second thoracic endosternite. It passes directly downwards as a narrow muscle, and is inserted on the anterior margin of the coxopodite.

The muscles of the exopodite have the same arrangement as the similar parts in the third maxillipede.

The muscles of the **flabellum** are large and powerful. The flabellum lies on the dorsal side of the gills, and by repeated rhythmical movements keeps the surface of the gills free from sand and mud.

The *extensor* (*ex. fl.*) is a short broad muscle arising from the upturned edge of the sternum in this somite. It passes outwards across the mouth of the cavity of the coxopodite, and is inserted on the inner side of the base of the flabellum.

The *anterior flexor* (*a.f.fl.*) is a fairly broad muscle arising from the posterior face of the last cephalic endopleurite, immediately above the foramen of the latter. It passes downwards, and is inserted on the anterior edge of the base of the flabellum.

The *posterior flexor* (*p.f.fl.*) is an extremely broad muscle arising from the last cephalic endopleurite, above the origin of the previous muscle. It runs downwards behind the extensor of the coxopodite, and is inserted on the posterior edge of the base of the flabellum.

VIII. Second maxillipede. This appendage is similar to the third maxillipede in structure, and its muscles have the same arrangement (see below).

The extensor muscle of the coxopodite arises from the inner side of the second thoracic epimeron, and the flexor arises from the upper end of the anterior face of the second thoracic endosternite. All the muscles of the basi-ischium are attached to the lower end of the anterior face of the second thoracic endosternite. The muscles of the flabellum are quite small, but have the same parts as described in the first maxillipede.

IX. Third maxillipede (fig. 30).

**Coxopodite.** There is a small extensor and a larger flexor.

The *extensor* muscle arises on the inner side of the third thoracic epimeron, and is inserted on the outer side of the coxopodite by means of a narrow tendon (*ex. C.*).

The *flexor* muscle is attached to the anterior wall of

the third endosternite. It passes outwards, and is inserted on a broad tendon (*f. C.*) at the inner side of the coxopodite.

**Basi-ischium.** There are two chief muscles.

The *extensor* is a small muscle arising from the anterior wall of the third thoracic endosternite. It is inserted on the ventral side of the basi-ischium by means of a small tendon (*ex. B.*).

The *flexor* is a larger muscle arising near the origin of the extensor. It is inserted on a long tendon (*f. B.*) on the dorsal side of the basi-ischium. There is also a small accessory flexor inserted on the outer side of the larger flexor.

There is one flexor and one extensor for each of the remaining segments of the endopodite. The muscles of the meropodite and carpopodite are fairly large. Those of the propodite and the dactylopodite are small.

The **exopodite** has two small muscles—a dorsal extensor and a ventral flexor.

The **flagellum** of the exopodite is flexed in its natural position. There is a large *extensor* muscle (*ex. fl.*) running the whole length of the exopodite, which is attached to the outer edge of the flagellum and by its action raises the latter. I have not been able to make out a flexor muscle. Probably the flagellum falls back into its natural flexed condition by means of the elasticity of the arthrodial membrane.

The flagellum in each of the maxillipedes is very active, and is constantly moving with great rapidity.

X. Chela.* (fig. 21, Text fig. 10).

**Coxopodite.** There are two muscles—a posterior

* In all the pereiopods it is probable that those muscles which are situated in the dorsal region of the pleural muscle chambers arise, not only from the walls of the latter, but also from the carapace in this region (Pl. IX, fig. 56, *fl.m.*)

extensor pulling the coxopodite backward and an anterior flexor pulling it forward.

The *extensor* is situated in the outer and posterior region of the fourth thoracic pleural muscle chamber. It arises from the anterior and posterior walls of the latter and passes forward and downward. Its insertion is on a long narrow tendon arising from the posterior side of the coxopodite (fig. 21, *ex. C.*, Text fig. 10, *d.*).

The *flexor* is a much larger muscle than the extensor, and lies in the fourth thoracic sternal muscle chamber. It arises from three parts of the endophragmal system—(1) from the posterior face of the third thoracic endosternite; (2) from the inner side of the third endopleurite; and (3) from the anterior face of the fourth thoracic endosternite. It passes downward and forward, and is inserted on an extremely broad tendon on the anterior side of the coxopodite (fig. 21, *f. C.*, Text fig. 10, *c.*).

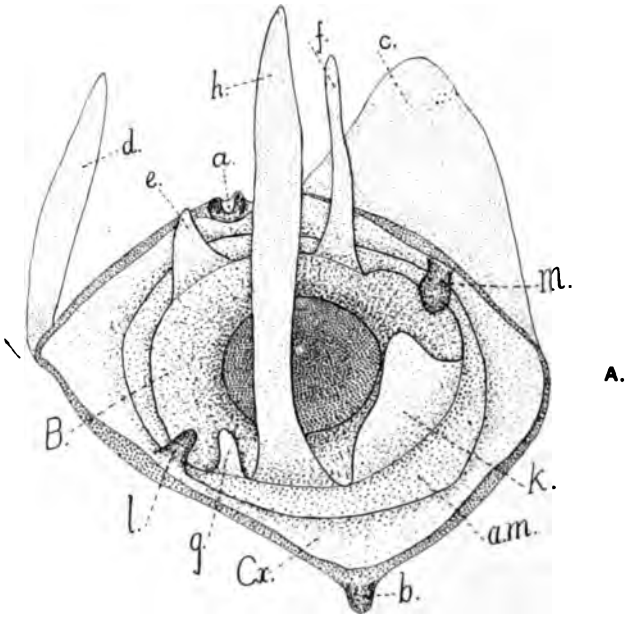
**Basi-ischiopodite.** There are two extensors and three flexors inserted on the proximal region of this segment.

The *anterior extensor* is situated in the anterior and ventral portion of the fourth thoracic pleural muscle chamber. It arises from the ventral part of the anterior and inner walls of the chamber. It runs outward, and is inserted on a long and narrow tendon situated immediately above the anterior hinge (fig. 21, *a. ex. B*, Text fig. 10, *f.*).

The *posterior extensor* is a small muscle situated almost entirely in the base of the coxopodite. It is attached to the ventral part of the wall of the fourth pleural muscle chamber. It passes outward, and is inserted on a small tendon which is immediately above that of the anterior extensor (fig. 21, *p. ex. B.*, Text fig. 10, *e.*)

The *anterior flexor* lies in the ventral region of the

fourth sternal muscle chamber, and arises from the fourth thoracic sternum. Its course is outward, upward and backward, and at its outer extremity it is inserted on a broad tendon lying on the ventral side of the basi-ischium, mid-way between the two hinges (fig. 21, *a. f. B.*, Text fig. 10, *k.*).




V.

FIG. 10.—The proximal end of the chela, after all the soft tissues have been removed. The tendons of the muscles moving the coxa and basi-ischium are shown. (The upper side of the figure is dorsal, and the right side is the anterior end.)

*Coxopodite.*—*a.* = dorsal hinge; *b.* = ventral hinge; *c.* = tendon of flexor muscle; *d.* = tendon of extensor muscle.

*Basi-ischium.*—*e.* = posterior extensor muscle; *f.* = anterior extensor muscle; *g.* = lesser posterior flexor muscle; *h.* = greater posterior flexor muscle; *k.* = anterior flexor muscle; *l.* = posterior hinge; *m.* = anterior hinge.

The *greater posterior flexor* lies in the outer and anterior portion of the fourth pleural muscle chamber,

and its origin is on the anterior wall of the latter. It passes downward behind the anterior extensor, and is inserted on an extremely long tendon which arises from the joint immediately behind the tendon of the anterior flexor (fig. 21, *p. f. B.*, Text fig. 10, *h.*).

The *lesser posterior flexor* is situated on the inner and anterior region of the fourth pleural chamber. It passes outward, and is inserted on a small tendon in front of the posterior hinge (Text fig. 10, *g.*).

The **Meropodite** has very little movement, and the muscles are extremely small.

The *extensor* is a small muscle arising from the posterior wall of the ischium. It passes downward and backward, and is inserted on a small tendon on the ventral side of the meros (fig. 21, *t. ex. M.*).

There does not appear to be a definite flexor muscle, but when the extensor muscle relaxes, the weight of the distal portion of the limb is sufficient to produce the small amount of flexion necessary.

**Carpopodite.** There is an anterior flexor and a posterior extensor muscle.

The *extensor* arises from the posterior walls of the meros throughout its entire length. The insertion of the muscle is on a long tendon situated near the dorsal hinge of the carpos. This tendon lies in the dorsal part of the meros and extends almost to the proximal end of the latter (*ex. C.*[1]).

The *flexor* has its origin on the anterior walls of the meros. Its tendon is similar in size to that of the extensor. It lies in the ventral region of the meros, and arises from the antero-ventral border of the carpos (*f. C.*[1]).

**Propodite.** There is a posterior extensor and an anterior flexor muscle.

The *extensor* arises from the posterior walls of the

carpos, and is inserted on a broad tendon at the posterior side of the propodite (*ext. P.*).

The *flexor* has its origin on the anterior wall of the carpos, and is inserted on a large tendon at the anterior side of the propodite (*f. P.*).

**Dactylopodite.** There is a dorsal extensor and a ventral flexor.

The *extensor* is comparatively small, and arises from the dorsal or posterior walls of the propodite. It is inserted on to a narrow tendon which is situated immediately above and between the two hinges of the dactylos (*ext. D.*).

The *flexor* is an extremely large muscle which occupies the greater portion of the propodite. It arises from the ventral and anterior walls of the latter, and is inserted on a very broad tendon which is attached to the ventral side of the dactylopodite (*f. D.*).

XI. First walking leg (Pl. III, fig. 22).

**Coxopodite.** There is a posterior extensor and an anterior flexor.

The *extensor* is situated in the fifth pleural muscle chamber. It passes downward, and is inserted on a long narrow tendon immediately behind the dorsal hinge (*ex. C.*).

The *flexor* is a large muscle situated in the anterior and upper portions of the fifth sternal muscle chamber. Its origin is partly on the anterior wall of the chamber and partly on the median plate. It passes outward and downward, and is inserted on a broad tendon on the anterior portion of the coxopodite (*f. C.*).

**Basi-ischiopodite.** There is one dorsal extensor and one ventral flexor muscle.

The *extensor* occupies the dorsal and posterior portion

of the fifth sternal muscle chamber. It arises from the anterior face of the fifth thoracic endosternite, and passes outward and downward, and is inserted on a long tendon on the dorsal side of the basi-ischium (*ex. B.*).

The *flexor* lies in the ventral and posterior part of the fifth sternal muscle chamber. It arises from the median plate, and passes downward and outward. Its insertion is on a fairly broad tendon on the ventral side of the joint (*f. B.*).

In addition to the above flexor there is a small accessory flexor muscle on each side of the former. They are probably comparable to the anterior flexor and lesser posterior flexor of the corresponding segment of the chela.

The muscles of the other segments of this limb are very similar to those described above in the chela. The two muscles of the dactylopodite, however, are extremely small, and almost equal in size.

XII. Second walking leg.

The muscles here are similar to those of the first walking leg.

**Coxopodite.** The *extensor* arises from the sixth pleural muscle chamber. The *flexor* arises from the sixth sternal muscle chamber.

In the **Basi-ischiopodite** both muscles arise from the sixth sternal muscle chamber.

XIII. Third walking leg.

The muscles are similar to those of the two previous appendages.

**Coxopodite.** The *extensor* arises from the seventh pleural muscle chamber. The *flexor* arises from the seventh sternal muscle chamber.

In the **Basi-ischiopodite** both muscles arise from the seventh sternal muscle chamber.

XIV. Fourth walking leg (Pl. III, fig. 23).

In the coxopodite and basi-ischium there are the same muscles as in the other walking legs. There is, however, an additional extensor of the coxopodite. This *ventral extensor* is inserted on a small narrow tendon (*v. ex. C.*) immediately below the insertion of the dorsal extensor.

The muscle chamber in this somite is not divided into pleural and sternal regions. Hence it may be designated the pleuro-sternal muscle chamber (see section on Endophragmal System). All the muscles of the coxa and the basi-ischium arise from this chamber.

The dorsal extensor of the coxopodite arises from the anterior wall of the chamber; the ventral extensor from the median plate; the flexor of the coxopodite from the anterior end of this muscle chamber. The extensor of the basi-ischium arises from the anterior and inner corner of the chamber, and the flexor has its origin on the median plate.

The muscles of the remaining parts of this appendage are similar to those of the other walking legs.

In the chela the coxa swings horizontally. In the first walking leg the coxa is slightly tilted, so that it swings forward and slightly downward. In each of the succeeding walking legs the corresponding part is more tilted, and in the last walking leg the ventral hinge of the coxa is more posterior and the dorsal hinge anterior. So that, instead of swinging horizontally as in the chela, the coxa swings in a plane inclined at a considerable angle to the vertical, and during the movement of extension the limb is capable of being turned almost on to the dorsal side of the carapace. The presence of the additional extensor muscle undoubtedly aids such a movement.

This freedom of movement is probably not of much

value in Cancer. In the swimming crabs, however, where the last thoracic appendages are flattened and oar-like and are utilised as an effective rowing organ, such an arrangement is of no mean importance.

Muscles of the fore-gut. These are described in the section on the Alimentary Canal.

The Dorso-ventral muscles are described in the section on Respiration.

It is of interest to note in passing that in the case of those muscles arising from the carapace, there are definite marks on the outside of the shell corresponding in shape and size to the areas of the origin of these muscles. It has been stated above (section on Integument) that the muscle is not directly attached to the chitinous exoskeleton, but arises from the basement membrane underlying the epidermis. How, then, can the marks of the muscle attachments be duplicated on the outer side of the exoskeleton?

The most probable explanation is that in those regions where the muscles are attached to the basement membrane the cells of the epidermis are in some way affected by the underlying muscles. In this manner the rate of secretion of the integument may have been slightly reduced in these localised areas, thus producing the marks on the outer side of the carapace.

### Muscles of the Abdomen.

On account of the third, fourth and fifth somites being fused together, the abdominal muscles of the male abdomen differ from those of the female.

Female abdomen (Pl. IV, figs. 32, 33).

There are two sets of muscles working each somite,

a pair of dorsal extensors, and a pair of ventral flexor muscles.

**Somite I.** Each *extensor* (*ex.* 1) arises as a broad band of muscle from the top of the epimeral region of the last two thoracic somites. It passes inward and backward, and is inserted on the side of the anterior triangular portion of the tergum of the first somite.

Each *flexor* (*f.* 1) muscle arises from the "sella turcica" in the thorax, and passes backward near the median line. It is inserted on a small ingrowth of the sternum immediately in front of the arthrodial membrane separating the first sternum from the second.

**Somite II.** Each *extensor* (*ex.* 2) is inserted on a small concavity in the tergal region of the first somite. It passes backward, and is inserted near the middle line on a tendon which is attached to the anterior extremity of the second somite.

Each *flexor* (*f.* 2) arises from the posterior face of the ingrowth, or tendon, at the posterior end of the first sternum. It passes backward near the median line, and is inserted on the anterior face of a similar tendon at the posterior extremity of the second sternum.

**Somite III.-VI. and Telson.** The muscles in the succeeding abdominal somites have the same arrangement as those of the second somite. The flexor of the last abdominal somite is not inserted on a well-marked tendon. The same applies to both the origin and insertion of the flexor muscle of the telson.

Uropod of female (Pl. IV, fig. 25).

In their natural position the uropods are extended and lie almost horizontal, with their distal extremities pointing toward the posterior end of the abdomen.

The **Protopodite** is capable of two kinds of movement. First there is a movement in an antero-posterior

plane. The flexor muscle, which has very little power, moves the protopodite forward, and the extensor acts in the opposite direction.

The *extensor* (*ex. prot.*) arises from the posterior region of the tergum of the somite to which the uropod belongs. It passes forward and downward, and is inserted on a small tendon on the anterior wall of the protopodite, some distance below the proximal border of the latter.

The *flexor* (*f. prot.*) arises from the anterior region of the tergum. It passes downward and inward, and its insertion is on a tendon arising from the outer border of the protopodite.

The protopodite also has a slight movement from side to side. The flexor muscle draws the appendage toward the middle line and the extensor pulls it outward.

The *lateral extensor* (*l. ex. prot.*) arises from the outer region of the tergum, and passes downward and inward. Its insertion is on a tendon arising from the outer border of the protopodite.

The *lateral flexor* (*l. f. prot.*) arises from the inner part of the tergum. It passes downward and outward, and is inserted on a tendon arising from the inner border of the protopodite.

**Exopodite.** The movement of the exopodite is lateral. There is one extensor and two flexors.

The *extensor* (*ext. ex.*) arises from the outer edge of the protopodite. It passes downward, and is inserted on the inner wall of the exopodite some distance below the arthrodial membrane.

The *flexors* (*d. f. ex.*, *v. f. ex.*) arise from the inner wall of the protopodite. They pass outward, and converge to a single insertion on the inner edge of the exopodite.

The **endopodite** is fused to the protopodite, and has no muscles.

Male abdomen.

There are no extensors between the third and fourth somites, and also between the fourth and fifth somites.

According to Williamson, there are only two long flexors at each side arising from the thorax. One is inserted on the sternum of the united third, fourth and fifth somites, and the other is inserted on the telson.

**Uropods of Male.** These muscles have been described by Williamson.* In the first appendage the endopodite has a strong flexor muscle. The extensor is extremely small, and probably the flexion is effected by the elasticity of the arthrodial membrane. The protopodite has two small muscles, one of which flexes and the other rotates the limb. In the second appendage there is also a strong flexor in the endopodite. The protopodite has a system of small muscles which rotate, extend and flex the appendage.

## Histology of Muscle.

The muscles of Cancer are composed of striated fibres. Each fibre is an elongated multi-nuclear cell which reveals, in longitudinal sections and in stained preparations, two kinds of striations—longitudinal and transverse. As a rule, the cross striations are the more obvious, and produce the "striped" appearance so characteristic of Arthropod muscle fibres.

Each fibre is composed of numerous longitudinal fibrils, which give rise to the longitudinal striations. In a transverse section across a fibre it is seen that the fibrils have an unequal distribution, and are usually grouped together into polyhedral areas (Cohnheim's areas). The bundle of fibrils constituting a single area is known as a *muscle column*. The various muscle columns are separated

* Williamson, H. C. *Twenty-second Annual Report of the Fishery Board for Scotland*, p. 104.

from one another by the sarcoplasm (protoplasm), which varies in quantity in different kinds of fibres.

In stained preparations the muscle fibre reveals alternate light and dark cross-striations. At its centre, each light band is interrupted by a transverse line (Krause's membrane). There is also a transverse line stretching across the middle of the dark band (Hensen's line). The latter is only seen with difficulty. Each portion of a fibril between two adjacent Krause's membranes is known as a "sarcomere."

Haycraft's* experiments led him to believe that the cross striations are due to regularly-occurring varicosites, and some of the preparations made in the course of the present work appear to show this. It is doubtful whether this structure (even if admitted) is alone sufficient to account for the fact that the cross-striations seen in fresh tissue are accentuated under the action of various staining reagents. It is highly probable, as suggested by Schäfer, that the cross striation of the fibrils is due to the heterogeneous nature of the latter.

An examination of the fresh muscles of a crab reveals the interesting fact that—as in the vertebrates—some of the muscles are of a darker colour than others. Sections across the muscle fibres show that, generally speaking, the "dark" muscles have much more sarcoplasm than the "light" ones. Hence Knoll distinguished between *plasmic* (dark) and *aplasmic* (light) fibres. Biedermann† has shown that there is a definite relationship between the amount of sarcoplasm present in a fibre and the nature of the work performed by the fibre. He has, furthermore, stated that "the elements of those muscles which serve

* Haycraft, J. B. "Cause of Striation of Voluntary Muscular Tissue," *Q.J.M.S.*, Vol. XXI (1881).

† Biedermann, W. *Electro-physiology*, Vol. I.

the most persistent or most strenuous action are richest in sarcoplasm."

In Cancer the muscles present all grades of colour, from an opaque yellowish brown (muscles of scaphognathite) to a transparent white (muscles of appendages). Undoubtedly, the most active muscles of the body are those of the scaphognathite, and probably the flexors and extensors of the abdomen are the most sluggish (in the Macrura the abdominal muscles are very strenuous). I append a list of muscles, commencing with the most strenuous and darkest in colour and finishing with the least active. In all cases the position of a muscle on the list for colour agrees with its position regarding its activity.

1. Muscles of the scaphognathite.
2. Muscles of the heart.
3. Mandibular muscles.
4. Anterior cardiac muscles.
5. Extensor muscles of flagella of maxillipedes.
6. Gastric muscles (other than the anterior cardiacs).
7. Muscles of the appendages.
8. Extensor and flexor muscles of the abdomen.

## COELOM AND BODY CAVITY.

Arthropods in general are characterised by the presence of a greatly reduced coelom in the adult. This reduction of the coelom is the result of the increase in the blood-holding spaces or sinuses. This system of swollen sinuses, which contain the venous blood, has produced a series of cavities lying between the various organs of the body, and has been termed by Lankester a *haemocoel*. The theory of Phleboedesis formulated by Lankester to account for the development of the haemocoel is as follows:—

"The system of blood-containing spaces pervading the body in Mollusca and Arthropoda is not, as sometimes supposed, equivalent to the coelom or perivisceral space of such animals as the Chaetopoda and the Vertebrata, but is in reality a distended and irregularly swollen vascular system the equivalent of the blood-vascular system of Chaetopoda and Vertebrata."*

In Cancer the only remnants of the true coelom are the gonadial sacs and the end sacs of the antennary glands. The labyrinth and bladder of the excretory system are lined by cells derived from epiblast.

## ALIMENTARY CANAL

### (Pls. V, VI, VII).

The alimentary canal extends from the *mouth*, which is situated on the ventral side of the cephalic region between the mandibles, to the *anus* on the ventral side of the telson. The nature of the development of the alimentary canal suggests a natural division into three parts:—(1) The *fore-gut*, which is the embryonic stomodaeum, (2) the *mid-gut*, the archenteron of the embryo, and (3) the *hind-gut*, which is the embryonic proctodaeum.

### Fore-gut.

The fore-gut commences at the mouth and is formed of the embryonic epiblast. It is lined throughout by a cuticle which is continuous with the exoskeleton around the mouth. The mouth leads into a short *oesophagus* (Pl. VI, fig. 40, *oe.*) which opens into the so-called "stomach," which is continuous behind with the mid-gut.

The mouth is situated on the ventral surface of the

* Lankester, E. Ray. "The Enterocoela and the Coelomocoela," *A Treatise on Zoology*, Part II.

cephalic region, and is bounded in front by a fleshy lobe—the *labrum* (Pl. III, figs. 18, 20, *lab.*) or anterior lip—and behind by the *metastoma* (*met.*) or posterior lip. On each side of the mouth are the mandibles.

Both the labrum and metastoma have closely packed glands which have the appearance and structure of the "salivary glands" found in the walls of the oesophagus. It is not inconceivable that they have the same function as the oesophageal glands. The mandibles also have at their base a mass of glands which are continuous with those in the ventral portion of the oesophageal walls.

In the **oesophagus** (Pl. V, fig. 35) the epidermal cells (*ch. ep.*) are of great length. In a soft crab with a carapace 25 mm. in width these cells are 90 $\mu$ in length and only 3 $\mu$ wide. On the outer side of the epidermis is a thin chitinous layer about 8 $\mu$ in width. This consists of two layers - a thin outer structureless layer, the cuticle, and a broader inner layer showing evidences of longitudinal striations. On the inner side of the epidermis is a well-marked basement membrane. Below the basement membrane is a layer of connective tissue (*der.*) about 370 $\mu$ in width. This is composed of a dense reticulate mass formed of intercrossing connective tissue fibres. There are also small connective tissue cells scattered about. Embedded in the connective tissue are numerous glands which may conceivably be salivary glands, but which I designate the *oesophageal glands* (*sal. g.*).

On the outer side of the connective tissue of the oesophagus is a layer of circular muscles—the *constrictors of the oesophagus* (*c. oe.*)—and passing through the connective tissue and attached to the basement membrane are numerous muscle bundles—the *dilators of the oesophagus* (*oe. l.*).

Each oesophageal gland is globular and consists of

numerous large conical cells, the apex of each cell pointing to the centre of the mass. Each cell has a well-defined nucleus near its outer side. In the centre of each gland mass is a small cavity into which the secretion from the individual cells is poured. This small central cavity is connected with the lumen of the oesophagus by means of a long narrow duct which passes between the cells of the epidermis. The duct and its walls is probably formed of a single cell, in which case the gland duct is intracellular. These glands are scattered through the connective tissue of the oesophageal wall. They take the stain distinctly, and have a diameter of 25 $\mu$ to 35 $\mu$ in the small crab mentioned above. From the above description it would appear that the oesophageal glands are merely modified cutaneous glands.

At the extreme ventral end of the oesophageal wall at each side there is an additional mass of such glands which are very closely packed together (*v. oe. g.*). As mentioned above, these glands are continuous with those of the mandible.

The large and spacious region of the fore-gut which follows the oesophagus is generally termed the "stomach;"* and is divided into a large anterior portion —the *cardiac chamber* (*card.*) and a smaller posterior portion -the *pyloric chamber* (*pyl.*).

The **Cardiac fore-gut** (Pl. V, fig. 34, Pl. VI, fig. 40, *card.*) is a large simple sac roughly spherical in shape. The cuticle lining this part of the alimentary canal

* The term "stomach" is an unsatisfactory one, as this part of the fore-gut is neither embryologically nor physiologically what is generally recognised as a stomach. Also the terms "cardiac" and "pyloric" have no meaning when applied to the Malacostraca, seeing that the cardiac region—as pointed out by Huxley—is the farthest from the heart. It would be inconvenient, however, to reject the terms "cardiac" and "pyloric," as such a change would also involve an alteration in the names of numerous ossicles and muscles connected with the fore-gut. The terms "cardiac fore-gut" and "pyloric fore-gut" will be used in the present Memoir.

presents numerous thickenings to form an elaborate system of plates and teeth known as the "Gastric Mill." This will be described below.

The posterior wall of the cardiac fore-gut is invaginated on its ventral surface to form the *cardio-pyloric valve* separating the cardiac region from the pyloric region.

The **Pyloric fore-gut** (Pl. V, figs. 34, 36) presents a very complicated arrangement.

In the posterior two-thirds of the pyloric region the chitin of the ventral wall is thickened at each side to form the *pyloric ampullae* (*amp.*). These are clearly seen from the outside as swellings on the floor of the pyloric region. The ampullae have their chitinous lining thrown into well-defined longitudinal parallel ridges. From the summits of the ridges there are numerous fine setae projecting into the cavity of the pyloric chamber. Each seta has numerous small hook-like branches. The two ampullae meet in the mid-ventral line in a well-defined ridge the *inter-ampullary fold* (Pl. V, fig. 36, *i. a. f.*).

The ventro-lateral walls immediately above the ampullae have the chitin enormously thickened at each side to form cushion-like pads projecting into the cavity of the pyloric chamber immediately above the ampullae. These are the *supra-ampullary ridges* ["voûte ampullaire," Mocquard] (*amp. c.*). Each cushion has a convex surface which faces inwards and downwards, and the upper parts almost meet in the middle line. The presence of the supra-ampullary ridges and the inter-ampullary fold causes the cavity and the ventral part of the pyloric chamber to be reduced to a narrow two-rayed fissure. The supra-ampullary ridges are covered with numerous fine setae, which stretch across the narrow lumen of this

portion of the pyloric chamber, so as to form—as Huxley suggested—a very effective filtering apparatus.

The dorsal part of the pyloric chamber has a comparatively large cavity. In transverse sections through the pyloric region the lateral walls of the dorsal portion are roughly at right angles to one another.

The supra-ampullary wall (fig. 36, *s. amp.*) is immediately above the supra-ampullary ridges, and is almost horizontal, thus forming the floor of the upper region.

The pleuro-pyloric wall (*pp.*) is on the outer side of the supra-ampullary wall and turns upwards almost at right angles to the latter. This portion of the wall may be complicated by the presence of folds (*up. f.*).

The dorsal wall is simple in structure.

Thus in the posterior two-thirds of the pyloric region the lumen is divided into a wide dorsal portion and a narrow ventral portion, the two parts being capable of complete separation by the concrescence of the inner portions of the supra-ampullary ridges.

The anterior third of the pyloric region is comparatively simple, and shows no such division into dorsal and ventral portions.

It is probable that in the anterior part of the pyloric region the contents undergo a certain amount of separation. For instance, any hard shell-like structures belonging to the creatures taken in as food will be separated from the soft and nutritious parts. The hard parts pass backwards along the wide dorsal chamber, and by means of an elaborate system of valves they are carried directly into the hind-gut without coming into contact with the unprotected walls of the mid-gut (fig. 40, *val.*). The valves are flap-like structures projecting backwards from the upper side of the posterior end of the fore-gut.

As suggested by Huxley and Mocquard the function of these valves may be partly to prevent the waste matter from passing back into the fore-gut, but Cuénot has claimed that the valves are also used, as described above, for carrying the hard waste pieces directly into the hind-gut. The mid-gut is not lined with chitin, and consequently the sharp pieces present amongst the food in the alimentary canal would be liable to tear the walls of the mid-gut.

The soft parts of the aliments are passed through the narrow ventral portion of the pyloric region, where they are sieved by the setae stretching across the lumen, and near the posterior region of this region the food comes into contact with the secretion from the digestive glands. The latter open into the ventro-lateral wall of the mid-gut immediately behind the ampullae, and the digestive fluid flows forward and mixes with the food in the ventral part of the pyloric region.

In the cardiac and pyloric regions we have essentially the same histological arrangements as in the oesophagus. The epidermis consists of columnar epithelium of much less length than the cells of the oesophageal epidermis. The chitinous layer is very thin except in the regions of the ossicles of the gastric mill, which are merely thick portions of the chitin which have become strongly calcified. The basement membrane is well marked and the connective tissue is a very thin layer. Embedded in this layer are very thin bands of circular and longitudinal muscles.

Mid-gut (or Mesenteron) (Pl. V, fig. 34, *m. g.*).

The mid-gut is an extremely short portion of the alimentary canal, being only about 10 mm. long in a full-grown crab. This is the only part of the alimentary

canal which is derived from the archenteron and is lined by cells formed from the hypoblast.

From the mesenteron arise a pair of caeca—the so-called "pyloric caeca." This is an unfortunate designation, as they do not arise from the pyloric region of the fore-gut. I therefore propose to substitute the name of **Mid-gut caeca** (fig. 34, *caec.*). Each caecum arises from the side of the anterior part of the mid-gut. It passes forward as a narrow tube alongside the pyloric chamber, and is closely applied to the postero-lateral region of the cardiac chamber of the fore-gut. On a level with the widest part of the latter the caecum terminates in a much convoluted portion.

The digestive glands (fig. 34, *di. gl.*) arise at each side from the ventro-lateral region of the mid-gut, immediately behind the origin of the mid-gut caeca. These will be described more fully below.

The epithelium lining the mid-gut (Pl. X, fig. 61) consists of columnar cells having a length of 55 $\mu$ in an adult crab. There is no cuticular lining to the epithelium of this region, but each cell has an outer striated border from 1 $\mu$ to 2 $\mu$ in thickness. This is similar to the "Härchensaum" present in the mid-gut of Anurida* and in the duodenum of many vertebrates. It is very probable that this striated border is characteristic of the mid-gut epithelium of arthropods in general, and probably the thin cuticle lining the mid-gut of Ligia described by Hewitt† is a similar structure.

In many of the epithelial cells are refractive bodies, probably the fat globules mentioned by Cuénot. Beneath the epithelium is a thick basement membrane. In the comparatively broad layer of connective tissue beneath the basement membrane are thin layers of circular and longitudinal muscles.

* Imms. *L.M.B.C. Memoir*, "*Anurida*."

† Hewitt. *L.M.B.C. Memoir*, "*Ligia*."

## Hind-gut (Pl. V, fig. 34, *h. g.*)

The hind-gut or intestine is a long narrow tube extending from the posterior end of the mid-gut to the anus which opens on the ventral surface of the telson. Near to the mid-gut it passes below the median bridge-like portion of the reproductive organs; passing further back it runs beneath the pericardium, and a short distance behind the latter it enters the abdomen, along which it pursues a straight course. Just before entering the abdomen the hind-gut gives off from its right side a long coiled tube—the **hind-gut caecum** (fig. 34, *i. caec.*).

The caecum lies above the hind-gut, and the coils, which are packed very closely together, extend into the first segment of the abdomen.

The hind-gut has very pronounced columnar epithelium (Pl. X, fig. 62). This is lined by a thin chitinous layer, consisting—as in the fore-gut—of an outer cuticle, and a layer longitudinally striated which appears to be continuous at the anus with the pigment layer of the exoskeleton. The epithelium rests upon a basement membrane outside of which are thin layers of circular and longitudinal muscles.

In the walls of the hind-gut immediately behind the mid-gut there are closely packed glands very similar in structure to those present in the walls of the oesophagus.

There are also glands, having a similar structure to the above, present in the walls of the hind-gut in the abdominal region. They are not closely packed (fig. 62).

## Digestive Gland.

The digestive gland ("liver," "hepato-pancreas") (Pl. V, figs. 34, 37, 38, 39) is a large yellowish-brown*

* This colour is due to lipochrome. (Miss Newbigin, *Journ. Physiol.*, Vol. XXI., p. 237, 1897.)

organ occupying nearly the whole of the ventral side of the anterior region of the cephalothorax. It is a lobulated structure composed of a large number of digitate tubular outgrowths, and arises from the mid-gut at each side. The front edge of the gland sweeps backward close to the antero-lateral border of the carapace and resembles the latter in having a notched edge. The posterior border of the gland is generally on a level with the anterior region of the branchial chamber: in other words, the branchial chamber is only covered by the digestive gland at its anterior end. Posteriorly the gland occupies the ventral part of the region between the muscles of the thoracic walking legs, and below the pericardium and hind-gut. Throughout the digestive gland is covered by the gonads (Pl. VIII, fig. 51). The gland does not extend into the abdomen.

Arising from the mid-gut at each side there are three main ducts which communicate with smaller ducts. These branch repeatedly, and ultimately end in the cavities of the tubules of which the main part of the gland is composed. Thus the tubules have a cavity which is continuous with that of the mid-gut, and both the ducts and the tubules are lined by cells derived from the embryonic hypoblast. Each of the main ducts mentioned above receives the digestive ferments from one of the three main lobes into which each half of the gland is divided. These lobes are as follows (fig. 34):—(1) An antero-lateral lobe having its outer border marked by notches which correspond to the markings of the antero-lateral border of the carapace; (2) a postero-lateral lobe lying above the anterior part of the branchial chamber; and (3) a posterior lobe which lies between the muscles of the thoracic walking legs.

## Histology of the Digestive Gland

(Pl. V, figs. 37, 38, 39).

In sections the tubules are seen to be closely packed together, generally being separated only by a very thin layer of connective tissue (fig. 37, *c.t.*) or a small blood sinus. Sometimes, however, the walls of the tubules are not separated from each other by any tissue. The lumen of the tubules has four angles in transverse section, and the cells at the angles are much shorter than the others.

The *ducts* are lined by a single layer of large columnar and non-glandular cells. In the sections stained with methyl-blue eosin these cells take the stain more readily than the cells of the tubules.

The *tubules* (fig. 37) have three kinds of cells.

(1) **Fat cells** (fig 37, *f.c.*, fig. 38). These are columnar cells from 70 $\mu$ to 120 $\mu$ in length and 15 $\mu$ wide. The contents of the cells are vacuolated, due to the presence of fat globules (fig. 38, *g.f.*). The border of each cell in contact with the lumen of the tubule is striated (*sb.*). The nucleus (*n.*) is generally situated in the inner portion of the cell.

(2) **Ferment cells** (fig. 37, *fm.c.*, fig. 39). These are not quite as long as the fat cells, but they are about four times as broad. Each cell contains a large globular mass (fig. 39, *f.v.*) which nearly fills the whole cell. These masses are yellowish-brown and are responsible for the characteristic colour of the digestive gland. According to Frenzel each mass is enclosed in a bladder, and the vesicles are more abundant during feeding time than during the fasting periods. On the side of the cell in contact with the lumen of the tubule there is a small amount of vacuolated protoplasm which exhibits striation. The border of the cell in contact with the lumen was

described by MacMunn as being ciliated. This is highly improbable, and it is more likely that we have in both the ferment cells and the fat cells a striated hem (Härchensaum) (*sb.*) similar to that already described in the mid-gut epithelium. The nucleus is situated in that portion of the cell farthest removed from the lumen.

(3) **Young cells** (fig. 37, *y. c.*). These are small cells found between the larger cells near the periphery of the tubules. These young cells stain deeply and will eventually give rise to the fat cells or ferment cells.

## Physiology of the Digestive Gland.

As pointed out by Cuénot, the digestive gland has many functions, which may be summarised as Digestion, Absorption, Excretion, Elimination and Regulation.

**Digestive function.** According to MacMunn, Frenzel and others the gland is a pancreas, and the ferments produced (proteolytic and amylolytic) are poured into the ducts of the gland and thence into the mid-gut. The ferments are produced entirely in the ferment cells.

The fat cells have the power of forming and storing fat.

Roaf* found that the action of the extract of the digestive gland was as follows:—

It does not digest coagulated white of egg. It digests fibrin most actively in alkaline solution, but not actively in acid solution. It converts starch into sugar, and inverts cane sugar. It does not hydrolise olive oil, but it hydrolises methyl acetate.

**Function of absorption.** According to Cuénot the digestive gland is of great importance as an accessory organ for absorbing the products of digestion. The

* Roaf, H. E. "A Contribution to the Study of the Digestive Gland in Mollusca and Decapod Crustacea." *Bio-Chemical Journal*, Vol. I, Nos. 8 and 9.

mid-gut is the only portion of the alimentary canal not lined with chitin, and therefore the absorption of the soluble products of digestion can only take place in this region. It is inconceivable that the short mid-gut, even with the mid-gut caeca, can be the *only* region where the process of absorption is carried on. The digestive gland, which is merely an outgrowth from the mid-gut, is richly supplied with blood, and it is an easy matter for the fluids to pass from the mid-gut into the tubules and through the cells into the blood stream. Thus the digestive gland becomes an accessory absorptive organ of no mean importance.

**Excretory function.** It was observed by Cuénot and MacMunn that when a Crustacean was injected with certain colouring matters, the latter were discovered in the ferment cells of the digestive gland as well as in the cells of the recognised excretory organ. Cuénot is of the opinion that the pigment contained in the excretory cells is of an excretory nature, and that when the contents of these cells ultimately find their way into the alimentary canal, the excretory pigment becomes separated from the ferments and passes down the hind-gut to the exterior.

**Function of elimination.** During the process of absorption, Cuénot states that the cells of the digestive gland keep back many useless products which are afterwards carried to the exterior together with the excretory products. This is quite distinct from the excretory function.

**Function of regulation.** In addition to the other functions it is probable that the digestive gland is capable of regulating the composition of the blood, especially with regard to the quantity of water contained in the blood.

Summary. As the food enters in at the mouth it will come into contact with the secretion from the

oesophageal glands. In the cardiac region of the fore-gut the food is broken up in a very effective manner. Passing back into the pyloric chamber, the food encounters the cardio-pyloric valve. Here the large pieces are prevented from passing into the pyloric chamber. The food which passes into the latter chamber probably undergoes a further process of sifting, the useless material passing along the dorsal portion of the pyloric chamber and the food being passed along the ventral portion. In this ventral region the food first comes into contact with the digestive ferments. Both are well mixed by the action of the muscles of the pyloric chamber.

As already stated, the probable regions of absorption are the mid-gut, mid-gut caeca and the tubules of the digestive gland. The waste products pass down the long hind-gut to the exterior.

## Ossicles of the Fore-Gut.

(Pl. VI, figs. 40, 41, 43, 44.)

In certain regions of the fore-gut the chitinous lining is thickened and strongly calcified to form *ossicles*. These ossicles give attachment to muscles. One set of ossicles in the dorsal and lateral walls of the cardiac region are connected with three tooth-bearing ossicles. This system of plates which is worked by the anterior and posterior gastric muscles (see section on Muscles of the Fore-gut) forms a very effective apparatus for breaking up the food which has passed into the cardiac fore-gut. Hence the name *gastric mill*.

In addition to the ossicles of the gastric mill there are " supporting ossicles " in both the cardiac and pyloric regions. To these supporting ossicles are attached the various muscles of the fore-gut.

## Ossicles of the Gastric Mill.

The **Mesocardiac Ossicle** (*m.c.*) is a small median ossicle in the dorsal wall of the cardiac region. It is triangular in shape, with the apex pointing forwards. It is not clearly separated from the urocardiac ossicle which passes posteriorly, and it is only partially separated from the pterocardiac ossicle which extends laterally. The ossicle is thicker dorso-ventrally at its posterior end, and to the thickened posterior edge the anterior ends of the cardio-pyloric muscles are attached. In the Macrura and the Anomura the mesocardiac ossicle is much larger than in the Brachyura, and the pterocardiac pieces are much smaller.

One pair of **Pterocardiac Ossicles** (*pt.c.*). They are situated to the right and left of the mesocardiac piece and in contact with it. The posterior border is almost straight, and the anterior border is curved. Each ossicle is broadest on its inner side, and tapers towards its outer extremity. Near the inner border of each ossicle is a smooth area where the anterior gastric muscle is inserted. Each ossicle extends outwards, and its outer extremity articulates with the zygocardiac ossicle by means of the *antero-lateral ligament* (*lig.*).

One pair of **Zygocardiac Ossicles** (*z.c.*) lying in the supero-lateral wall of the cardiac region of the fore-gut. Each passes backwards and inwards, and comes into contact at its posterior end with the exopyloric ossicle, thus forming a connecting link between the ossicle of the cardiac and the pyloric regions. The zygocardiac ossicle is irregular in shape. The anterior part is rod-like, but the ossicle becomes gradually broader as it passes backwards, and the posterior portion is a broad rectangular plate which bears the lateral tooth. One side

of the ossicle points inwards, and the other faces outwards. The inner face is concave and the outer face is convex. The inner edge of the ossicle folds outwards so as to produce a deep groove on the outer side below the convexity. The ossicle has four borders. The *anterior border* is concave and terminates at its posterior extremity in the large anterior tooth. The *dorsal border*, which can be seen through the dorsal wall of the stomach, is also concave. It passes backwards and inwards and ends at the posterior border. The *posterior border* has a large indentation into which the anterior border of the exopyloric ossicle fits. The *inner border* lies obliquely, being nearer the middle line at its anterior end. The ossicle appears to be much thicker at its inner border than in any other region. This thickness is not real, but is merely due to the ossicle folding outwards at its inner border. This inner border bears the *denticles*. Anteriorly there is a large single denticle, which is followed by about seven smaller denticles, which point inwards and decrease in size from before backwards. The folded edge of the inner border is crossed by about twenty-four transverse ridges. This system of denticles and ridges on the zygocardiac ossicle is known as the **lateral tooth** (*lat. t.*).

The **Exopyloric Ossicles** (*ex. py.*) are a pair of small triangular plates, each of which lies between the posterior border of the zygocardiac ossicle and the pyloric ossicle. The superior border gives support to the posterior end of the outer part of the cardio-pyloric muscle, and on its external face it provides insertion for the external part of the posterior gastric muscle.

The **Urocardiac Ossicle** (*u.c.*) is a median plate more or less fused with the mesocardiac ossicle in front. It passes backwards and downwards as a broad, thin rectangular plate. At its posterior end, which articulates

with the propyloric ossicle, it bears the large blunt **median tooth** (*med. t.*) on its ventral surface.

The **Propyloric Ossicle** (*pr.p.*) is a small median plate situated almost vertically. When the gastric mill is at rest the lower end of this ossicle is considerably behind its upper end. Its upper end articulates with the front portion of the pyloric ossicle, and its lower end is in contact with the posterior end of the urocardiac ossicle. The plate is roughly triangular in shape and its apex, which points downwards, is bifurcated. The base of the triangle is dorsal and is extremely concave. The ossicle is highly calcified around the edges, but in the centre it is almost membranous.

The **Pyloric Ossicle** (*o.py.*) is a median ossicle lying between the two exopyloric ossicles which articulate with it at each side. It covers the anterior part of the pyloric region of the stomach. Its central portion is membranous, but laterally it is slightly calcified. These lateral calcifications indicate that the pyloric ossicle is really a paired structure. In the Macrura all signs of the double origin disappear.

### Cardiac "Supporting Ossicles."

The **Pectineal Ossicles** (*pec.*) are a pair of irregular hammer-shaped ossicles, each lying in the lateral wall of the fore-gut beneath the posterior portion of the zygocardiac ossicle. The curved "handle" of the hammer points anteriorly. On the inner side of the "head" of the hammer are three claw-like teeth. These are the **lateral accessory teeth** (*a.t.l.*). ["Infero-lateral cardiac teeth," Huxley.]

The **Prepectineal Ossicles** (*p.pec.*) are a pair of long narrow rod-like ossicles, each being concave on its inner border and extending upwards from the pectineal ossicle

to the outer edge of the zygocardiac ossicle with which it articulates by means of a ligament.

One pair of **Post-pectineal Ossicles** (*pt. pec.*) Each is a narrow rod-like ossicle which passes backwards from the pectineal ossicle to the posterior wall of the stomach. It then suddenly turns downwards and runs down the posterior wall of the cardiac fore-gut as a straight rod. At its lower end the ossicle turns forwards for a short distance. On the internal border of the ossicle there is a row of setae projecting into the stomach.

The **Infero-lateral Cardiac Ossicles** (*i.l.*) are a pair of long rod-like ossicles, each of which lies immediately behind and parallel to the rod-like portion of the post-pectineal ossicle. Dorsally the ossicle is in contact with the sub-dentary ossicle, and ventrally it terminates on a level with the lower end of the post-pectineal ossicle. The ossicle is broader at its upper end and tapers gradually towards its lower extremity.

There is one pair of **Sub-dentary Ossicles** (*s.dt.*) At its anterior end each ossicle is in contact with the inner border of the zygocardiac ossicle. The ossicle passes downwards and backwards as a somewhat curved rod, and its posterior end touches the upper end of the infero-lateral cardiac ossicle.

The **Lateral Cardio-pyloric Ossicles** are a pair of small ossicles articulating with the posterior and upper end of the infero-lateral cardiac ossicles.

**Postero-lateral Cardiac Plates** (*cd. pl.*). These are a pair of broad plates roughly quadrangular in shape, each lying in front of the post-pectineal ossicle. It is a membranous area having no decided calcification, but being distinctly thicker than the ordinary wall of the stomach. There are two rows of long setae arranged along the posterior edge of each plate and projecting into the cavity of the stomach.

The **Antero-lateral Cardiac Plates** (*cd.al.*) are a pair of thickened areas in the side walls of the stomach in front of the postero-lateral cardiac plates, but they are not so well defined as the latter.

The *Cardio-pyloric valve* (*c.p.v.*) is the thickened median portion of the posterior wall of the cardiac fore-gut. Its upper end is invaginated into the floor of the fore-gut so as to form an incomplete partition between the cavities of the cardiac and pyloric regions of the fore-gut. The top of the cardio-pyloric valve is richly clothed with setae.

### Pyloric "Supporting Ossicles."

In the *dorsal wall* of the pyloric fore-gut there are three pairs of ossicles.

The **Anterior Mesopyloric Ossicles** (*a.mes*) are a pair of small ossicles lying immediately behind the pyloric ossicle near the median dorsal line.

The **Posterior Mesopyloric Ossicles** (*p.mes.*) are a pair of small ossicles lying behind the anterior pair.

The **Uropyloric Ossicles** (*u.py.*) are a pair of small ossicles lying in the roof of the posterior part of the pyloric region and immediately behind the posterior mesopyloric ossicles.

In the *ventral wall* of the pyloric fore-gut the main supporting ossicles are as follows:—

The **Antero-inferior Pyloric Ossicle** (*a.i.p.*) is a median plate shaped somewhat like a truncated triangle. The base of the triangle points forwards and comes into contact with the cardio-pyloric valve. This ossicle lies in front of the inter-ampullary groove.

The **Pre-ampullary Ossicles** are a pair of small plates. Each lies at the side of the antero-inferior pyloric ossicle and immediately in front of the pyloric ampulla.

The **Postero-inferior Pyloric Ossicle** is a median curved rod-like ossicle. It is concave anteriorly, and is situated behind the pyloric ampullae.

In the *lateral walls* of the pyloric fore-gut there are the following principal ossicles:—

On the supra-ampullary walls there are three pairs of ossicles, viz., the **Anterior** (*a.s.a.*), **Middle** (*m.s.a*), and **Posterior** (*p.s.a.*) **Supra-ampullary Ossicles.**

There are also three pairs of ossicles in the pleuro-pyloric walls, viz., the **Anterior, Middle** and **Posterior Pleuropyloric Ossicles.**

The positions of these six pairs of ossicles are indicated by the names.

## Muscles of the Fore-gut. (Pl. VII.)

Mocquard* has divided the muscles of the fore-gut into two kinds. The *extrinsic muscles* are those muscles which have points of origin on some part of the skeletal system outside the fore-gut, and which are inserted on to ossicles lying in the walls of the fore-gut. The *intrinsic muscles* are attached at both ends to ossicles lying in the walls of the fore-gut.

### Extrinsic Muscles.

**Anterior Gastric Muscles** (*g.a.*)—one pair. Each muscle has its origin on the procephalic process. Both pass directly backwards near the median line, being only slightly separated from one another, and are inserted on the front of the pterocardiac ossicles near the middle line.

**Inner Posterior Gastric Muscles** (*g.p.i.*)—one pair. They arise from two small calcareous projections, almost median in position, situated on the under side of the mesogastric region of the carapace. Each muscle passes

* Mocquard, *Annales Sciences Naturelles*, 6 ser., t. 16, 1883, p. 238.

downwards and forwards, and is inserted on the front part of the pyloric ossicle.

**Outer Posterior Gastric Muscles** (*g.p.e.*)—two pairs. The two muscles at each side run together so that they may be mistaken for a single muscle. They arise from the under side of the mesogastric region of the carapace, some distance in front of the origin of the dorsal pyloric dilator muscles, but not so near the middle line. They pass downwards, forwards and inwards, and are inserted on the external face of the exopyloric ossicle.

The above three sets of muscles are concerned in the working of the gastric mill. In addition to these the intrinsic muscles—the cardio-pyloric muscles—to be described later, are also used in connection with the gastric mill.

The following muscles serve to dilate the fore-gut:—

**Upper Anterior Dilator Muscles** (*a.s.*)—one pair. Each arises from the inner side of the cephalic sternum immediately behind the orbit. The muscle is not a compact one, but passes backwards, upwards and inwards as a series of muscular strands which gradually diverge. They are inserted on the anterior and outer corner of the fore-gut.

**Lower Anterior Dilator Muscles** (*d.ai.*)—one pair. These are a smaller pair of muscles than the preceding. They are very close to the middle line so as to appear almost as a single median muscle. Each arises on the upper side of the epistoma near the middle line and passes backwards and slightly upwards, being inserted on the lower part of the front wall of the fore-gut near the median line. As in the preceding case, the muscle is composed of several separate strands which diverge as they approach the point of insertion.

**Antero-lateral Dilator Muscles** (*d.la.*)—one pair.

These are narrow muscle bands each arising about half way along the outer edge of the roof of the pre-branchial chamber. Each passes inwards and downwards parallel to the front edge of the carapace and is inserted on the lateral wall of the cardiac region of the fore-gut, above the oesophagus.

**Postero-lateral Dilator Muscles** (*d.lp.*)—one pair. These are broad muscles arising near the point of origin of the preceding muscles. Each passes directly inwards and slightly backwards and downwards. The muscle broadens considerably as it approaches the fore-gut. Its insertion is on the anterior edge of the postero-lateral cardiac plate.

**Dorsal Pyloric Dilator Muscles** (*d.sup.*)—two pairs—anterior and posterior The two muscles at each side run close together so that it is difficult to distinguish the separate muscles. They arise close together from the under side of the carapace just behind the origin of the outer posterior gastric muscles. They pass downwards and slightly forwards and are inserted on the ossicles of the dorsal wall of the pyloric region of the fore-gut. The anterior muscles are inserted on the posterior meso-pyloric ossicles and the posterior muscles on the uropyloric ossicles.

**Ventral Pyloric Dilator Muscles.** Two pairs—outer and inner. Each of the *inner pair* (*i.py.i.*) is a long narrow muscle arising near the base of the mandibular apophysis. It passes upwards and slightly backwards on the inner side of the posterior oesophageal dilator muscle and runs very close to the posterior wall of the cardiac region. It is inserted on the antero-inferior pyloric ossicle in the ventral wall of the pyloric region. Each of the *outer pair* (*i.py.e.*) is much shorter than the inner pair. Its origin is on the endopleurite of the first maxillary

segment. From this the muscle passes upwards and is inserted on the ventral pyloric wall on the outside of the insertion of the inner pair.

The following muscles dilate the oesophagus:—

**Upper Anterior Oesophageal Dilator Muscles** (*oe.as.*) —one pair. Each of these muscles arises from the epistoma close to the origin of the upper anterior dilator muscle. Passing backwards and slightly upwards below the latter muscle, it is inserted on the anterior wall of the oesophagus. The muscle is not compact, but is made up of separate strands which diverge as they approach their insertion.

**Lower Anterior Oesophageal Dilator Muscles** (*oe.ai.*). One pair of very small muscles. Each arises from a small eminence on the posterior part of the epistoma near the middle line. These eminences are behind the origin of the previous muscle. The muscle passes backwards below the previous muscle, and its insertion on the anterior wall of the oesophagus is immediately below that of the previous muscle.

**Lateral Oesophageal Dilator Muscles** (*oe.l.*)—one pair. Each of these muscles is made up of three distinct bands of muscle fibres. Near its origin the muscle is compact, but the fibres diverge as they approach the oesophagus. Each muscle arises near the extreme posterior angle of the epistoma and passes inwards below the upper muscle. Its insertion is on the lateral wall of the oesophagus.

**Posterior Oesophageal Dilator Muscles** (*oe.p.*)—one pair. Each muscle arises from the top of the pillar-like portion of the endopleurite of the first maxillary segment and passes inwards and downwards. It runs external to the inner ventral pyloric dilator, and crossing over that muscle it is inserted on the posterior wall of the oesophagus.

Intrinsic muscles.

**Cardio-pyloric Muscles** (*c.py.*) These consist of one median and two lateral muscles. The *median* muscle extends from the thickened posterior border of the meso-cardiac ossicle to the upper edge of the propyloric ossicle. The *lateral* muscles extend from the mesocardiac ossicle to the exopyloric ossicle. These muscles are used in connection with the gastric mill and are concerned in bringing the ossicles of the mill back to their original position after each series of complicated movements effected by means of the gastric muscles.

**Lateral Cardiac Muscles** (*c.lat.*)—three pairs. The three muscles at each side may be distinguished as the *upper*, *middle* and *lower* muscles respectively. The *upper muscle* arises from the upper edge of the infero-lateral cardiac ossicle and passes upwards and forwards as a broad sheet of muscle to the dorsal border of the zygocardiac ossicle. The *middle muscle* also arises from the upper edge of the infero-lateral cardiac ossicle below the origin of the upper muscle and passes upwards and forward parallel to this muscle. It is inserted on the prepectineal ossicle, and also on the anterior part of the dorsal border of the zygocardiac ossicle. This muscle is much narrower than the previous one. Both sheets of muscle are broader at their insertion than at their origin. The *lower muscle* is a short broad sheet arising from the side of the infero-lateral cardiac ossicle, and passing across the upper portion of the postero-lateral cardiac plate. Its insertion is on the antero-superior border of this plate. According to Mocquard, these muscles raise the cardio-pyloric valve.

The **Postero-inferior Cardiac Muscle** (Fig. 48, *c.i.*). This is a median broad sheet of muscle covering the

posterior wall of the cardiac region of the fore-gut. It is attached at each side to the posterior border of the infero-lateral cardiac ossicle.

**Anterior Cardiac Muscle** (*c.ant.*). This is a median muscle extending as a broad and thin sheet down the front wall of the fore-gut. It arises in the median line on the front of the mesocardiac ossicle and passes forwards. As it passes downwards along the front wall of the fore-gut it divides into two main branches, which are attached separately to the front wall of the fore-gut.

The above muscle must not be confused with the muscle of the same name described by Mocquard. The latter muscle is on the antero-lateral wall. I therefore designate it the **Antero-lateral Cardiac Muscle** (*c.al.*). There is one pair of these muscles, each being situated on the antero-lateral wall of the fore-gut immediately above the oesophagus. It is attached to the anterior border of the membranous antero-lateral cardiac plate, and passes upwards almost to the median line.

The above two sets of muscles act as constrictors of the cardiac portion of the fore-gut.

**Circular Oesophageal Muscles** (*c.oe.*). These are present as a broad band running around the oesophagus and acting as constrictors of the oesophagus.

**Lateral Pyloric Muscles** (*py.lat.*). There are several pairs of muscles—some broad and others very small—arising at each side from the upper part of the post-pectineal ossicle and the infero-lateral cardiac ossicle. They pass upwards and are inserted on the various ossicles of the lateral and dorsal walls of the pyloric region of the fore-gut. These muscles serve as constrictors of this region of the fore-gut.

## The Mechanism of the Gastric Mill.

According to Huxley* the movement of the gastric mill is effected by means of *both* the anterior and posterior gastric muscles. By the contraction of these muscles the urocardiac tooth is thrown forward, and simultaneously the zygocardiac teeth are rotated inwards and the three teeth meet in the middle line.

Mocquard has been fortunate enough to observe the movements in a living Stenorhyncus having a remarkably transparent carapace. He states that the active movement is brought about *almost solely* by means of the anterior gastric muscles. If the posterior muscles act at all, it is only very feebly and spasmodically. When the anterior gastric muscles contract, the urocardiac ossicle and the median tooth are thrown forward. The movement is slightly complicated because of the connection between the posterior part of the urocardiac ossicle and the lower part of the propyloric ossicle. When in a state of rest the lower part of the latter ossicle lies considerably behind its upper border. As a result of the contraction of the anterior gastric muscle the lower part is drawn forward so that the ossicle takes up a vertical position. The median urocardiac tooth, if not in contact with the propyloric ossicle, would have a simple backward and forward movement. But the connection between the two ossicles causes the median tooth to move in an arc the convexity of which points downwards.

Since the anterior gastric muscles are inserted on the inner ends of the pterocardiac ossicles, the latter are also drawn forward when the muscles contract. This movement causes the outer ends of the ossicles to turn downwards and inwards. Because of the connection between

* Huxley, T. H. *The Crayfish.* [*International Science Series.*]

the pterocardiac and the zygocardiac ossicles the anterior handle-like portion of the latter are also drawn downwards and inwards. Posteriorly the zygocardiac ossicles are in contact with the exopyloric ossicles, which in their turn articulate with the pyloric ossicle. Therefore if we consider the zygocardiac and the exopyloric ossicles as a single rod, we have a lever of the second order, the fulcrum being at the anterior end and the weight in the region of the zygocardiac tooth. Thus, the application of the force at the anterior end rotates the tooth downwards and inwards, and the three sets of teeth meet in the middle line. When the muscles relax the ossicles spring back into their original position, partly because of the elasticity of their joints, but mainly by means of the action of the cardio-pyloric muscles.

## THE BLOOD VASCULAR SYSTEM

(Pl. VII, figs. 49, 50; Pls. VIII, IX).

Briefly stated the scheme of circulation is as follows. The pure blood returning from the gills passes into the Pericardium by means of the Branchio-cardiac veins. From the Pericardium the blood enters the heart through the ostia. From the anterior end of the heart there arise five arteries carrying the blood to the gonads, digestive glands, fore-gut, and the front part of the body. From the posterior region of the heart two median arteries arise which supply the abdomen and the appendages. The impure blood returning from the system does not pass to the gills along definite vessels, but flows through irregular spaces or *sinuses* between the various organs. The blood from the sinuses eventually reaches the gills and passes along the Afferent Branchial Sinuses on the outside of the gills. The blood is distributed to

the various gill lamellae where it is oxygenated. The pure blood leaves the gills by the Efferent Branchial Veins, running along the inside of the gills and which pass into the Branchio-cardiac veins.

The Pericardium (Pl. IX, figs. 54, 56, *Per.*) is a closed cavity surrounding the heart and having thin transparent walls. It is situated immediately beneath the cardiac region of the carapace, and between the "flancs." It lies above the hind-gut and covers the posterior portions of the digestive gland and gonads. When viewed from above the shape of the pericardium is roughly pentagonal (fig. 54). The base of the pentagon is anterior and the apex is posterior.

The Branchio-cardiac veins (Pl. IX, fig. 54, *bc* 1-5) enter each side of the pericardium by means of three wide openings which have no valves. The *first* opening is situated at the anterior corner of the pericardium and receives the first and second branchio-cardiac veins. The *second* opening is situated a little behind the first and receives the third branchio-cardiac vein. The *third* opening is situated at the postero-lateral corner, and at this point the fourth and fifth branchio-cardiac veins enter the pericardium.

The Heart (Pl. VII, figs. 49, 50) is a white semi-transparent body, pentagonal in shape when seen dorsally and having a rectangular shape when viewed from the side. Two angles of the pentagon are anterior and the other three are posterior. The heart is suspended in the pericardium by means of the *alae cordis* (fig. 49, 50, *cd.*1-6), which are bands of fibrous connective tissue stretching across from the angles of the heart to the wall of the pericardium. Each ala cordis appears to have a short band of muscle fibres attached to its outer extremity.

The alae cordis are eleven in number (fig. 49, 50).

*Dorsal Antero-lateral* (*cd.*1)—one pair. Stretching from the dorsal side of each of the antero-lateral corners of the heart to the corresponding corner of the pericardium.

*Ventral Antero-lateral* (*cd.*2)—one pair. Immediately beneath the dorsal antero-lateral band. Extending from the ventral side of each of the antero-lateral corners of the heart to the corresponding corner of the pericardium.

*Dorsal Postero-lateral* (*cd.*3)—one pair. Extending from the dorsal side of each of the postero-lateral angles of the heart to the corresponding angle of the pericardium.

*Ventral Postero-lateral* (*cd.*4)—one pair. Having a similar position to the dorsal postero-lateral band, but lying immediately beneath it.

*Median Posterior* (*cd.*5)—A single band arising from the dorsal side of the posterior angle of the heart and stretching across to the posterior angle of the pericardium.

*Posterior* (*cd.*6)—one pair. Arising ventrally from the postero-lateral side of the heart and crossing to the postero-lateral side of the pericardium.

The walls of the heart are also very muscular, and the cavity of the heart is crossed by numerous strands of muscle.

The blood enters the heart from the pericardium by means of the *Ostia*. There are three pairs of ostia—one pair at the anterior end of the dorsal wall of the heart (Figs. 49, 50. *a.ost.*), one pair at the posterior end of the dorsal wall (*p.ost.*), and the third pair are found in the lateral walls of the heart—one ostium at each side (*l.ost.*). Each ostium is valved so as to prevent the blood from returning to the pericardium.

## The Arteries. (Pls. VIII, IX.)

The following arteries are given off from the heart: At the *anterior* end (1) the median *Cephalic artery*, and on each side of this is (2) a *Lateral artery*, and (3) a *Hepatic artery*, all passing forwards. At the *posterior* end there are two median arteries arising about the same point, (4) the *Descending artery* passing downwards, and (5) the *Posterior Aorta* passing backwards above the intestine.

At its origin from the heart each artery is valved, so as to prevent the blood from returning.

**Cephalic artery** [Ophthalmic artery] (Pl. VIII, fig. 51. *o.art.*). This is a median artery arising from the anterior end of the heart. From its origin it passes directly forward above that portion of the gonads situated between the internal adductor muscles of the mandibles. It pursues a straight course over the pyloric and cardiac regions of the stomach and between the anterior gastric muscles. So far the course of the artery has been entirely superficial, but near the anterior end of the cardiac fore-gut it dips downward and divides into two branches immediately above the brain. Each branch passes outward and supplies the eyes and also the various parts of the front region of the head.

**Lateral artery** [Antennary artery] (Pl. VIII, Fig. 51. *a.art.*) There is one pair of lateral arteries, each of which arises from the anterior end of the heart a little outside of the origin of the cephalic artery. On leaving the heart the lateral artery passes outward, making an angle of about 40° with the cephalic artery. Almost immediately it passes through the outer portion of the internal adductor muscle of the mandible (*i. a. md.*). It then curves outward, sweeping around the stomach until it reaches the external abductor muscle of the mandible (*e. b. md.*). Here it divides into two parts—(1) an outer

portion, the **Ovarian** (*ov. a.*) [or **Spermatic**] **artery,** which follows the course of the gonads, and (2) an anterior portion, the **Antennary artery** (*a. art.*), which passes around the front of the fore-gut and supplies the organs in the region of the head.

The main portion of the lateral artery, after leaving the heart, dips down gradually until it reaches the external abductor muscle of the mandible (*e. a. md.*). The antennary artery still continues to pursue a deeper course, but the ovarian [or spermatic] artery becomes more superficial. When the gonads are well developed the main artery and the gonadial branch are partly embedded in the substance of the gonad, but when the reproductive organs are small these parts of the artery are quite superficial.

**Branches of Main Lateral artery—**

*Branch to the Hind-gut.* This arises on the inner side of the artery just behind the internal adductor muscle of the mandible. It passes downward and inward to that portion of the hind-gut beneath the front part of the heart.

*Branch to the Digestive Gland.* This is a large branch arising immediately in front of the branch to the hind-gut. It passes outward and gives off numerous branches to the digestive gland and also to the hypodermis in this region.

*Branch to the Cardiac Fore-gut.* In front of the internal adductor muscle of the mandible a large branch is given off on the inner side. It passes through the substance of the gonad and breaks up into a complicated network on the lateral and dorsal walls of the cardiac fore-gut. This branch supplies the muscles of the fore-gut.

*Branches to the Hypodermis.* Throughout the whole

course of the lateral artery and its branches small arteries are given off which supply the hypodermis.

*The Ovarian* [or *Spermatic*] *Branch* (*ov. a.*). This follows the course of the gonads, and sweeps round near to the outer edge of the carapace. Numerous branches are given off to the gonads and also to the hypodermis.

*The Antennary Branch* (*a. art.*). This passes anteriorly and dips downward as it sweeps around the fore-gut. It passes over the paragastric lobe of the bladder and divides into an outer and an inner portion. The *outer* branch dips downward and outward and gives branches to the external adductor muscle of the mandible. It then passes outward to the hypodermis and supplies also the hepatic lobe of the bladder. The *inner* branch passes inward and supplies the antennae and the front part of the head. It also sends branches to the anterior gastric muscles and to the main vesicle and the paragastric and oesophageal lobes of the bladder.

**Hepatic artery** (Pl. VIII, fig. 51, *h. art.*). Owing to the fact that this artery dips down immediately on leaving the heart, and becomes deeply embedded in the digestive gland, it is rather difficult to locate. Hence several workers at the Brachyura have neither figured nor described this artery, and some have described other arteries as the hepatic artery. Milne-Edwards,* in his description of Maia, has designated as the hepatic artery those branches of the sternal artery which supply the digestive gland. Brooks† has called the lateral (ophthalmic) artery by the name of hepatic artery.

The hepatic artery of each side arises from the ventral side of the anterior region of the heart, its origin being beneath and slightly external to that of the lateral

* Milne-Edwards. *Hist. Nat. des Crustacés.*

† Brooks. *Handbook of Invertebrate Zoology.*

artery. Immediately on leaving the heart it dips downward and makes an outward sweep in the deeper parts of the digestive gland. Near its origin on its inner side it gives off a branch which goes to the hind-gut. There are also other small branches which supply various parts of the gland. The main artery, however, divides into two branches, the posterior of which sweeps outward embedded in the posterior part of the digestive gland. The anterior branch passes beneath the gonad and the external adductor muscle of the mandible and supplies the anterior portion of the gland.

**Posterior aorta** (Superior abdominal artery) (Pl. VIII, fig. 51, Pl. IX, fig. 53, *sa. art.*). This arises as a median vessel from the posterior end of the heart. Just after leaving the heart it gives off at each side a small vessel. This passes forward and downward beneath the pericardium, and supplies those parts of the reproductive organs lying beneath the pericardium, and also some of the muscles of the Basi-Ischium of the Chela.

Immediately above the hind-gut caecum a second pair of branches arises. These are the **Postero-lateral arteries** (*pl. art.*), and have several complicated branches. The main branch passes outwards above the coils of the caecum and divides into two vessels. The anterior vessel passes forward and gives off branches to the extensor muscles of the coxopodites of the four walking legs. The posterior branch supplies the muscles extending from the "flancs" to the carapace, and also gives a rich blood supply to the coils of the hind-gut caecum.

Behind the origin of the postero-lateral arteries the posterior aorta enters the abdomen. As the arrangement in the two sexes is somewhat different, these will be described separately.

F e m a l e. The aorta passes down the abdomen

above the hind-gut, but not in the median line. As it passes backward it gradually crosses over to the right side. In each of the second, third, fourth and fifth abdominal segments a pair of arteries is given off to the appendages. At the posterior end of the fifth segment the aorta divides into two branches. The right branch follows the course of the aorta. The left branch crosses over the hind-gut and is continued down the left side of the hind-gut parallel to the right branch. Both branches pass into the telson, where they break up into fine branches. Throughout the abdomen small branches are given off from the posterior aorta to the hind-gut, to the abdominal muscles and the muscles of the abdominal appendages.

M a l e . There are only two pairs of arteries given off from the posterior aorta. These are in the first and second abdominal segments and supply the two pairs of appendages. As the aorta passes backward it crosses over to the *left* side, and in the fifth segment it bifurcates, the right branch crossing over the hind-gut. As in the female, there are also innumerable small arteries given off to the hind-gut and to the abdominal muscles.

**Descending artery*** (Pl. IX, fig. 56, *d. art.*). This leaves the heart at the posterior end close to the origin of the posterior aorta. It is an extremely wide vessel which passes almost directly downward on the right side of the hind-gut until it nearly reaches the anterior part of the "sella turcica," where it turns suddenly forward. It continues to pass downward and forward, and between the muscles of the fourth and fifth thoracic appendages it passes through the foramen

* The term *sternal artery* is generally given to this artery, as well as to its continuation along the ventral side of the thorax. I have, however, thought it more fitting to apply the term "sternal artery" only to the ventral portion.

of the coalesced thoracic ganglia. Immediately beneath the nerve chain the artery divides into a short and broad posterior branch and a much longer and narrower anterior branch. Both these branches are continuous and horizontal, and are known together as the *sternal artery.*

**Sternal artery** (Pl. IX, fig. 52, *S.art.*). This is a large and well-defined median artery lying in the thorax below the nerve cord and between the muscles of the thoracic appendages. It is broadest at its posterior portion just behind its connection with the descending artery (*j.d.*). In front of this connection it is continued forward as a much narrower vessel, from which are given off arteries to each of the post-oral cephalo-thoracic appendages, and also to the digestive gland. The arteries supplying these appendages arise separately from the sternal artery, except in the case of the last two pairs of thoracic appendages. The arteries supplying these appendages arise as a single vessel at each side of the posterior part of the sternal artery, each of which divides into two branches, each branch going to an appendage.

The blood supply of the last five pairs of thoracic appendages is very similar, and the artery supplying the chela may be taken as typical of all. This artery (*art.*6.) arises singly from the sternal artery and passes outwards. A short distance from its origin it gives off a large ventral branch which supplies the muscles of the coxopodite and basi-ischium. The main artery passes to the extreme end of the appendage, giving off various small branches to the various muscles of the limb.

Each of the arteries to the maxillipedes (*art.* 5), after giving off its ventral branch, enters the appendage and bifurcates, one branch going to the endopodite and the other to the exopodite.

The arteries supplying the first and second maxilli-

pedes (*art.* 3, *art.* 4) are not symmetrical. The origin of the artery going to the first maxillipede of the right side is posterior to that of the left. In the case of the second maxillipede the origin of the artery on the right side is anterior to that of the artery on the left.

Just in front of the branches to the first maxillipede the sternal artery bifurcates, each part passing forward and uniting again behind the mouth, thus forming a ring. From this ring arteries are given off to the mandibles and the first and second maxillae (*art.* 1, *art.* 2).

**Inferior Abdominal artery** (Pl. IX, fig. 52, *ia.art.*). The posterior part of the broad sternal artery is continued as a narrow vessel which runs backwards over the "sella turcica" and down the abdomen beneath the nerve cord and the hind-gut. It gives off a few small branches to the hind-gut and to the flexor muscles of the abdomen.

Blood Sinuses and Veins. (Pl. IX, figs. 54, 55, 56.)

The blood returning from the various parts of the body to the gills is not enclosed in definite vessels, but flows through irregular spaces known as *sinuses*. Generally speaking, all the main organs of the body, such as the alimentary canal, digestive gland, reproductive organs, muscles, &c., have blood sinuses in close contact with them.

Above the cardiac fore-gut there is a large sinus—the **Dorsal sinus**—which is situated above the epigastric lobe of the bladder. There is also a smaller sinus between this lobe of the bladder and the fore-gut. These two sinuses are connected in front.

The dorsal sinus passes down the front of the fore-gut and is connected ventrally with a sinus which passes backward beneath the stomach. At the level of the oesophagus this sinus divides into a right and left portion.

These **Sternal sinuses** pass backward at each side of the ventral part of the thorax between the leg muscles and beneath the pericardium. The two sternal sinuses are not definitely separated from one another, but are connected here and there by irregular sinuses. On the outer side each sternal sinus sends offshoots down the pleural muscle chambers to the base of the gills (fig. 56, *br. S.* 4). These branches or branchial sinuses again unite into a long sinus which runs along the base of the gills. This is the infra-branchial sinus (fig. 55, *i. s.*). The blood sinuses from each of the thoracic legs also pass into the infra-branchial sinus.

From the infra-branchial sinus the blood passes along the afferent branchial sinuses on the outside of each gill.

At the posterior end of the thorax the sternal sinuses are connected with a small abdominal blood sinus.

The sinuses in connection with the digestive gland—the **Hepatic sinus**—and the reproductive organs—the **Ovarian** [or **Spermatic**] **sinus**—open into the sternal sinus at each side. There is a very large sinus below the posterior part of the digestive gland.

The **Branchial sinuses** (*br. s.* 1-5) connect the sternal sinus with the infra-branchial sinus at each side. They are five in number at each side. The first branchial sinus (*br. s.* 1) commences below the anterior end of the pericardium. It passes down the pleural muscle chamber of the second thoracic segment and opens into the infra-branchial sinus near its anterior end. Similarly the second branchial sinus (*br. s.* 2) passes down the third thoracic pleural muscle chamber, the third sinus (*br. s.* 3) is in the fourth pleural chamber, the fourth sinus (*br. s.* 4) is in the fifth pleural chamber, and the last branchial sinus (*br. s.* 5), which commences below the posterior end of the pericardium, passes down the

pleural muscle chamber of the sixth thoracic segment. All the pleural sinuses are below the branchio-cardiac veins, which also run down the pleural muscle chambers.

The **Infra-branchial sinus** (fig. 55, *i. s.*) is a long sinus which runs along each side of the thorax at the base of the thoracic legs and the gills. Posteriorly it extends as far as the last walking leg, and anteriorly almost as far as the metastoma. Into it flow the five branchial sinuses from above, and from its outer and ventral side there enters a narrow sinus from each of the thoracic appendages. From its outer and dorsal side there is given off an afferent branchial sinus to each of the gills.

**Afferent Branchial sinuses** (fig. 55). These sinuses run along the outer side of each gill.

*First afferent branchial sinus* (*af.* 1) goes to the podobranch of the second thoracic somite.

*Second afferent branchial sinus* (*af.* 2) goes to the arthrobranch of the second thoracic somite.

*Third afferent branchial sinus* (*af.* 3) goes to the small podobranch of the third thoracic somite.

*Fourth afferent branchial sinus* (*af.* 4) goes to the anterior arthrobranch of the third thoracic somite.

*Fifth afferent branchial sinus* (*af.* 5) goes to the posterior arthrobranch of the third thoracic somite.

*Sixth afferent branchial sinus* (*af.* 6) goes to the anterior arthrobranch of the fourth thoracic somite.

*Seventh afferent branchial sinus* (*af.* 7) goes to the posterior arthrobranch of the fourth thoracic somite.

*Eighth afferent branchial sinus* (*af.* 8) goes to the pleurobranch of the fifth thoracic somite.

*Ninth afferent branchial sinus* (*af.* 9) goes to the pleurobranch of the sixth thoracic somite.

The **Efferent Branchial veins** (fig. 54) receive the pure blood from the branchial lamellae. They pass down

the inside of each gill. Each efferent branchial vein is a blood vessel having a definite wall.

There are nine efferent branchial veins (*ef.* 1-9) corresponding to the nine afferent branchial sinuses—one for each gill.

The **Branchio-cardiac veins** (fig. 54) convey the pure blood from the efferent branchial veins to the pericardium. There are five branchio-cardiac veins at each side. They have definite walls.

*First Branchio-cardiac vein* (*bc.* 1) receives the first and second efferent branchial veins. It passes up the outer side of the pleural muscle chamber of the second thoracic segment, above the first pleural sinus.

*Second Branchio-cardiac vein* (*bc.* 2) receives the third, fourth and fifth efferent branchial veins. It passes up the outer side of the third thoracic pleural muscle chamber. The first and second branchio-cardiac veins enter the pericardium together through the *first* opening (see section on Pericardium).

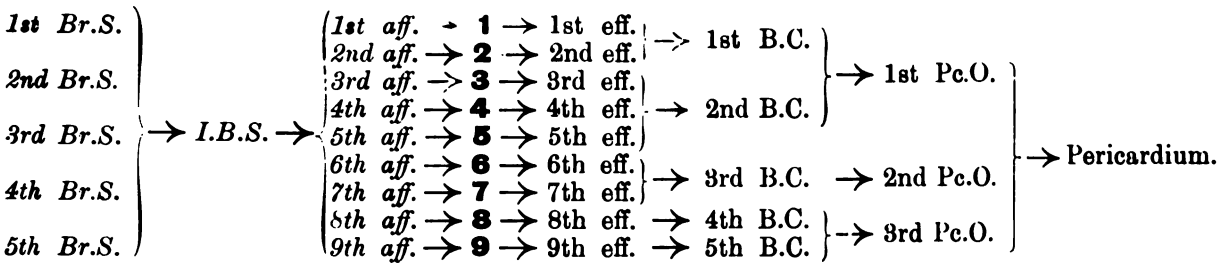
*Third Branchio-cardiac vein* (*bc.* 3) receives the sixth and seventh efferent branchial veins. It passes up the fourth thoracic pleural muscle chamber. It enters the pericardium by means of the *second* pericardial opening.

*Fourth Branchio-cardiac vein* (*bc.* 4) receives the eighth efferent branchial vein, and passes up the fifth pleural muscle chamber.

*Fifth Branchio-cardiac vein* (*bc.* 5) receives the ninth efferent branchial vein and passes up the sixth pleural muscle chamber. The fourth and fifth branchio-cardiac veins enter the pericardium through the *third* pericardial opening.

There are no valves between the branchio-cardiac veins and the pericardium

## Scheme of Circulation of the Blood to and from the Gills.


1st Br.S.
2nd Br.S.
3rd Br.S.
4th Br.S.
5th Br.S.
I.B.S.
1st aff. → 1 → 1st eff.
2nd aff. → 2 → 2nd eff.
3rd aff. → 3 → 3rd eff.
4th aff. → 4 → 4th eff.
5th aff. → 5 → 5th eff.
6th aff. → 6 → 6th eff.
7th aff. → 7 → 7th eff.
8th aff. → 8 → 8th eff.
9th aff. → 9 → 9th eff.
→ 1st B.C.
→ 2nd B.C.
→ 3rd B.C.
→ 4th B.C.
→ 5th B.C.
→ 1st Pc.O.
→ 2nd Pc.O.
→ 3rd Pc.O.
→ Pericardium.

### References.

**1** = Podobranch of 2nd thoracic segment.
**2** = Arthrobranch ,, ,, ,,
**3** = Podobranch of 3rd ,, ,,
**4** = Anterior arthrobranch of 3rd thoracic segment.
**5** = Posterior ,, ,, ,, ,,
**6** = Anterior ,, 4th ,, ,,
**7** = Posterior ,, ,, ,, ,,
**8** = Pleurobranch of 5th thoracic segment.
**9** = Pleurobranch of 6th ,, ,,

*Br.S.* = Branchial sinus.
*I.B.S.* = Infra-branchial sinus.
*aff.* = afferent branchial sinus.
eff. = efferent branchial vein.
B.C. = Branchio cardiac vein.
Pc.O. = Pericardial opening.

## The Blood.

The blood is an almost transparent fluid having a slight pinkish-blue tint (due to the presence of haemocyanin). The colour deepens on exposure to air. The blood consists of an almost colourless lymph in which are found numerous small cells or *amoebocytes*. There are two principal kinds of amoebocytes:—(1) Semi-transparent cells, which are amoeboid and have finely granular protoplasm. There is a well-defined nucleus. (2) Globular cells containing refringent granules. As pointed out by Cuénot,* these granules are similar to the eosinophilous granules recognised by Ehrlich in the leucocytes of various vertebrates. Hence Cuénot designates the second kind the *Eosinophilous amoebocytes*.† They are composed of an albuminous material.

In the neighbourhood of the cephalic artery, above the fore-gut, is a cellular mass which, according to Cuénot, is a lymphatic gland in which the amoebocytes are formed.

Cuénot has recognised five kinds of amoebocytes in the blood, which are all stages in the transformation of the clear amoebocytes mentioned above. The eosinophilous amoebocytes are also formed from the clear amoebocytes, and mark a stage in the degeneration of the cell. The eosinophilous granules present in the amoebocyte are small and few in number at first. They become comparatively large in size and very numerous until the entire cell is filled with a solid mass. The cell then degenerates rapidly and finally disappears. The granules

* Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, T. XIII, 1895, p. 245.

† The granules readily take the following stains:—Picric acid, eosin, indigo-carmine, fuchsine acid and "orange G." They remain absolutely colourless under the following stains:—Methyl green, dahlia, crystal violet, methylene blue and safranin. (CUÉNOT).

are probably dissolved in the lymph. The cells themselves are eaten by the young clear amoebocytes, which thus act as *phagocytes*. The phagocytic function is limited to the young cells only. After the appearance of the eosinophilous granules they cease to act as phagocytes.

Cuénot* claims also to have discovered a phagocytic gland which is quite distinct from the lymphatic gland. It is a swollen mass of cells situated on the terminal branches of the hepatic artery. The cells resemble the free amoebocytes and probably act as phagocytes.

When the blood ceases to flow, coagulation takes place. This is effected by the clear amoebocytes. These cells become changed in their appearance, and they send out numerous fine pseudopodia which unite with those of the neighbouring cells to form a network, in which all the cells are united together. Thus a clot is formed.

## The "Pericardial Pouch."

At each of the postero-lateral corners of the pericardium there is a structure which Cuénot† designated the "poche pericardiale." In Cancer each pouch lies on the upper part of the posterior thoracic epimera and projects into the branchial chamber. Externally, each pouch is covered with a cuticle which is continuous with the chitinous wall of the branchial chamber. The cavity of the pouch, which is continuous with the pericardial sinus, is to some extent broken up by connective tissue cells and by muscle fibres. The function of these pouches is unknown.

* Cuénot, L. *Comptes Rendus*, 1903 (No. 137), p. 619.

† Cuénot, L. "Études physiologiques sur les Crustacés Décapodes." *Archives de Biologie*, t. XIII (1895).

## RESPIRATORY SYSTEM.

(Pl. X, figs. 63, 64; Pl. XI, figs. 65, 66, 67).

### Respiratory Mechanism.

Respiration is effected by means of gills or branchiae, which are outgrowths from the walls of the thorax. The gills do not project directly on to the exterior, but are situated in the branchial chambers at each side of the cephalothorax.

The branchial chambers—one pair. The cavity of each chamber is morphologically a part of the exterior, and its walls are formed by the downgrowth of the carapace at each side. The sub-branchial region of the carapace is closely applied to the coxopodites of the pereiopods, and here turns inward to form the wall of the branchial chamber. In transverse section the chamber has a triangular shape (Pl. IX, fig. 56), and its walls may be spoken of as ventral, dorso-lateral and inner. The two former are membranous and are continuations of the inturned edge of the sub-branchial region.

The postero-lateral portion of the digestive gland rests upon the roof of the branchial chamber. Between the floor of the chamber and the sub-branchial region of the carapace there is a mass of connective tissue. In the anterior region of the chamber the floor is raised into a well defined transverse ridge. In a full-sized crab this groove is about $\frac{1}{4}$ inch in front of the anterior inhalent aperture. In sections through this ridge the epidermis is greatly elongated and has a glandular structure. There are also tegumentary glands below the epidermis. The podobranch of the second thoracic somite is closely applied to the posterior side of this ridge. For the sake of convenience I designate the latter the *branchial ridge*. Its probable function will be discussed below.

The inner wall is well calcified, and is formed by the thoracic epimera ("flancs"). The gills rest on the inner wall.

The development of the branchial chambers would tend to produce a stagnant layer of water around the respiratory organs. But the nature of their function requires that the gills should be in contact with water containing a normal amount of dissolved oxygen. So that, correlated with the formation of the branchial chamber, an arrangement has been effected for producing a constant stream of water over the gills. This necessitates two things—(1) inhalent and exhalent openings in connection with each branchial chamber, and (2) some mechanism for producing the current of water through the chambers.

In the Macrura the inhalent opening is situated between the inner edge of the branchiostegite and the base of the thorax. In Cancer, however, this opening is considerably smaller. Between the chela and the last pereiopod the sub-branchial region is closely applied to the base of the thorax, and the line of separation between the two is guarded by a thick growth of long setae, so that it is highly improbable that any water can gain entrance to the branchial chamber in this region. Above the last walking leg, however, there is a small slit opening into the posterior region of the branchial cavity. This is the **posterior inhalent aperture.** In front of the coxopodite of the chela there is a well-defined transverse opening leading into the anterior part of the branchial cavity. This is the **anterior inhalent aperture.** The latter is guarded in front by the coxa and flabellum of the third maxillipede, which, on their posterior borders, are clothed with long setae. There are also numerous setae on the anterior face of the coxopodite of the chela. These

two sets of setae probably strain the water as it passes through to the branchial chamber.

At its anterior end the branchial chamber is extremely shallow on account of the roof sloping down at a considerable angle. Above the branchial ridge, already referred to, there is an extremely narrow cavity between the top of the ridge and the roof of the chamber. This cavity is continued forward and inward into the pre-branchial chamber.

Pre-branchial chambers. One pair. They are situated at the side of the mouth, each being in front of and connected with the branchial chamber of the same side. Each chamber is produced by the ingrowth of the inner edge of the anterior part of the sub-branchial region of the carapace. Its walls, therefore, are continuous with those of the branchial chamber. The pre-branchial chamber is much smaller and shallower than the branchial chamber. On its anterior and inner side it is connected with the exterior by means of a wide opening—the **exhalent aperture.**

The current through the branchial and pre-branchial chambers is caused by the vigorous action of the scaphognathite. The latter lies in the pre-branchial chamber, and when at rest the anterior surface faces upward. Normally the scaphognathite displays the following movements:—The action of the extensor muscles tends to pull the ventral surface backward. This is followed by a sharp forward blow of the outer lobe of the scaphognathite, caused by the action of the outer flexors. This is immediately followed by an undulating movement of the inner lobe, caused by the accessory muscles and inner flexors. In this way the water is baled out of the exhalent aperture. This current from behind forward is probably assisted by the energetic action of the exopoditic flagella

of the maxillipedes. The extremely active motion of these flagella is quite obvious, and they probably form an accessory current-producing organ of no mean importance.

The normal current, as we have seen, flows from behind forwards, entering at the inhalent apertures and leaving by means of the exhalent aperture. In Corystes, Atelecyclas and Portumnus, Garstang* observed that the branchial current was sometimes reversed. Bohn† has extended these observations, and finds this phenomenon is of universal occurrence throughout the Brachyura. In Cancer the habit of reversing the branchial current does not appear to be very strongly developed. Bohn suggests that the reversal takes place in order to rest the fatigued muscles of the scaphognathite, as the energetic action is performed by different muscles in the two cases.

The flabella (epipodites) of the maxillipedes pass backward into the branchial chamber. That of the first maxillipede (*f.m.*[1]) is by far the largest, and extends backward throughout the whole length of the branchial chamber lying upon the gills. The flabellum of the second maxillipede (*f.m.*[2]) lies below the gills towards the dorsal side of the epimera. It only extends as far forward as the middle of the epimeron of the fourth thoracic somite. The flabellum of the third maxillipede (*f.m.*[3]) also lies below the gills and on the ventral and outer side of the second flabellum. Its proximal portion forms part of the anterior boundary of the anterior inhalent aperture. It extends backward to the posterior end of the epimeron

* Garstang. "The Habits and Respiratory Mechanism of *Corystes cassivelaunus*."—*Journal Marine Biological Association*, Vol. IV (N.S.), p. 223.

"The Respiratory Phenomena of *Portumnus nasutus*." *Journal Marine Biological Association*, Vol. IV (N.S.), p. 402.

† Bohn, G. "Sur la Respiration des Décapodes." *Bull. Sci. France et Belg.* T. XXXVI (Ser. 6), 1902, p. 178.

of the fifth thoracic somite. All three flabella are richly clothed with long setae.

In the living animal the flabella have a slow motion over the surface of the gills. Their main function is, undoubtedly, to keep the surface of the gills free from sand and mud which may be suspended in the water carried into the branchial chamber. In a crab from Port Erin the flabellum of the first maxillipede of the right side had been destroyed. In consequence of this the outer surface of the gills of the right side was covered with a layer of fine mud, which must have rendered the outer portions of the gills inoperative. It is doubtful whether the flabella have any function with regard to the formation or regulation of the current of water over the gills. At any rate, this function, if present, has not the importance ascribed to it by Claus.*

The description of the respiratory mechanism of the Brachyura given by Milne-Edwards has become almost classic, and has been accepted by most workers on the subject. According to this explanation, the water enters the branchial chamber at *one* place, viz., in front of the coxopodite of the chela. On entering the branchial chamber the current passes backward below the gills and then forward above the gills and out to the exterior through the pre-branchial passage.

This explanation has been disputed by Bohn,† who states that the water enters the branchial chamber throughout the entire length of the inner edge of the sub-branchial region, the entrance being especially marked at the anterior and posterior inhalent apertures ("l'orifice inspirateur antérieur et postérieur," Bohn). According to Bohn, the water entering by the anterior

* Claus. *Arbeit. Zool. Instit. Wien*, Bd. VI., Hft. 1.

† Bohn. *Op. cit.*

inhalent aperture does not pass backward but passes directly forward to the pre-branchial chamber, and only bathes the anterior part of the sixth gill and all the gills in front of this. The posterior gills are supplied by water entering the posterior inhalent aperture. He denies that there is a backward current caused by the flabella.

My own observations on these points are as follows:—There are two inhalent apertures—the anterior and posterior. Between these two apertures the inner border of the sub-branchial region is closely applied to the side of the thorax, and there appears to be absolutely no inflow of water along this border. Of the two inhalent apertures, the anterior is decidedly the most important. The current of water flowing in through the posterior aperture is very small. I think it extremely probable that some of the water drawn in at the anterior inhalent aperture passes backward, but I do not accept the explanation of Claus—that the backward current is caused by the flabella of the maxillipedes. The presence of the well-defined branchial ridge (see above) in the anterior part of the branchial cavity has suggested another explanation. The ridge is situated on the floor of the branchial chamber immediately in front of the anterior inhalent aperture. It arises near the inner side of the chamber, and passes in front of the aperture as a transverse wall. On the outer side of the aperture it turns backward and outward, and after extending half way down the branchial chamber, it gradually dies away. At its anterior end the branchial chamber is exceedingly shallow, so that the ridge almost extends to the roof of the chamber, leaving only a narrow slit which communicates with the pre-branchial cavity. As the water flows in through the anterior inhalent aperture, it will be drawn forward by the vigorous action of the scaphognathite.

The branchial ridge, however, will act as a formidable barrier, and although some of the water will undoubtedly pass directly over into the pre-branchial chamber, it is reasonable to suppose that some of it will have its course changed by the branchial ridge and will pass backward, following the direction of the latter.

### The Gills (Figs. 63, 64).

The gills arise from each side of the thorax and lie upon the inner wall of each branchial chamber, i.e., on the thoracic epimera. According to the terminology introduced by Huxley, the gills may be placed in three categories –the *podobranch* arising from an appendage, the *arthrobranch* arising between an appendage and the epimeron, and the *pleurobranch* arising from the epimeron.

In Cancer there are only nine gills at each side. The following is the branchial formula.

| Thoracic somites ..... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total. |
|---|---|---|---|---|---|---|---|---|---|
| Podobranch ..... | — | 1 | 1 | — | — | — | — | — | 2 |
| Anterior arthrobranch . | — | 1 | 1 | 1 | — | — | — | — | 3 |
| Posterior arthrobranch. | — | — | 1 | 1 | — | — | — | — | 2 |
| Pleurobranch ..... | — | — | — | — | 1 | 1 | — | — | 2 |
| Epipodite ..... | (1) | (1) | (1) | — | — | — | — | — | (3) |
| Total ..... | (1) | 2+(1) | 3+(1) | 2 | 1 | 1 | — | — | 9+(3) |

**First gill.** Podobranch of the second thoracic somite (figs. 63, 64, *g.* 1). It arises from the coxopodite of the second maxillipede between the exopodite and the flabellum. It lies with its outer face in contact with the posterior side of the branchial groove, and its inner face is closely applied to the basal portions of the gills 2 to 6. Its apex points backward and outward. Length 22 mm.*

**Second gill.** Arthrobranch of the second thoracic somite (*g.* 2). Arises from the arthrodial membrane of

* The measurements of the gills are taken from a crab having a carapace breadth of 12 cm.

the second maxillipede. It passes directly backward and lies upon the fused epimera of the first and second thoracic somites. Its long axis is at right angles to that of the first gill. Length 25 mm.

**Third gill.** Podobranch of the third thoracic somite (*g.* 3). Arises from the elongated coxopodite of the third maxillipede. It is extremely short and is wedged in between the first and fifth gills, at the base of the latter. Length 7 mm.

**Fourth gill.** Anterior arthrobranch of the third thoracic somite (*g.* 4). Arises, together with the fifth gill, from the arthrodial membrane of this somite. It lies on the thoracic epimera, immediately behind the second gill. Length 26 mm.

**Fifth gill.** Posterior arthrobranch of the third thoracic somite (*g.* 5). Arises from the same place as the fourth gill, and lies immediately behind the latter. Its base is notched in order to receive the third gill. Length 25 mm.

**Sixth gill.** Anterior arthrobranch of the fourth thoracic somite (*g.* 6). Arises together with the seventh gill from the arthrodial membrane between the chela and the fourth thoracic somite. It lies behind the fifth gill. Total length 37 mm.

**Seventh gill.** Posterior arthrobranch of the fourth thoracic somite (*g.* 7). Arises from the same place as the sixth gill and lies immediately behind it. Total length 37 mm.

**Eighth gill.** Pleurobranch of the fifth thoracic somite (*g.* 8). Arises from the epimeron of this somite. Total length 28 mm.

**Ninth gill.** Pleurobranch of the sixth thoracic somite (*g.* 9). Arises from the epimeron of this somite, upon which it lies, immediately behind the eighth gill.

Structure of a gill (figs. 65, 66, 67).

Each gill is of the phyllo-branchiate type. With the exception of the third gill, they are all pyramidal in shape, their apices pointing upward (with the exception of the first gill, in which the apex points backward). Along the outer side of each gill runs the afferent branchial vessel, and the efferent vessel is situated on the inner side. The gill is composed of numerous lamellae, which have the appearance of the leaves of a book. Each lamella is covered with a thin layer of chitin. This layer is also continued on the outside of the afferent and efferent vessels. The gills, therefore, are covered by part of the general chitinous exoskeleton, and at ecdysis this outer chitinous layer is cast with the remainder of the exoskeleton. In transverse section each gill is triangular (fig. 65). The efferent vessel is situated at the apex of the triangle, and the afferent vessel lies in the middle of the base of the triangle. Stretching across from the afferent to the efferent vessels is the *branchial septum* (*i. b. s.*), which separates the anterior from the posterior lamellae.

In the branchial septum between the afferent and efferent vessels transverse sections reveal the presence of scattered cells, generally having brown contents (fig. 67, *br. e.*). These are excretory cells, and together constitute the branchial excretory organ (see section on Excretory System). Cuénot* found that when a crab is injected with ammonium carminate or methylene green these substances are taken up by the excretory cells of the branchial septum. These cells, therefore, have the same reaction as the end-sac epithelium.

I have not been able to find any trace of the branchial glands discovered by Allen† in Palaemonetes. Cuénot,

* Cuénot. *Arch. de Biol.*, T. XIII, p. 245.
† Allen. *Q.J.M.S.*, Vol. XXXIV, p. 75.

however, has found them close to the efferent vessels in several of the Bracyhura. They do not appear to be present in Cancer.

In longitudinal sections through the gill (fig. 66) the lamellae are seen to be lined by epidermal cells (*ch. ep.*). There is a narrow cavity containing blood separating the upper and lower layer of cells. This cavity, or *lamellar sinus* (*l.s.*) is bridged over in certain parts by the junction of the two layers of epidermal cells. At the free edge of each lamella the lamellar sinus is continuous with the larger *outer lamellar sinus* (*o. l. s.*). This runs around the edge of the lamella, and the epidermal cells in this region are extremely flattened. Each lamellar sinus is in contact with the afferent branchial vessel on the outer side, and the efferent branchial vessel on the inner side. It is in the lamellae that the aeration of the blood is effected.

Dorso-ventral muscles (Pl. VIII, fig. 51, Pl. IX, fig. 56, *d. v. m.*).

Extending upward from the membranous roof of the branchial chamber to the carapace, is a series of muscles which may be termed the *dorso-ventral muscles*. The arrangement of these muscles will not be described in detail. There are three sets of muscles at each side (see fig. 51). The outer and middle series are arranged in two parallel lines running antero-posteriorly. The inner set is small, and is situated above the inner region of the branchial chamber. The roof of the chamber is considerably lower at the anterior end than in the posterior region, so that the anterior muscles are consequently longer than the posterior muscles.

Since the roof of the branchial chamber is soft and membranous, it is capable of considerable movement. The

contraction of the dorso-ventral muscles will effect the raising of the branchial roof, and thus produce a corresponding increase in the capacity of the branchial chamber. When the muscles relax, the weight of the superimposed digestive gland and gonad will be sufficient to depress the roof and decrease the volume of the branchial chamber.

Although it is difficult to understand the precise function of these muscles, it must be conceded that their action may be of supreme importance in connection with the branchial chamber, either as a current regulator or as an accessory current-producing organ. It will not be surprising if additional investigations on this point throw new light on some of the problems discussed above.

## EXCRETORY SYSTEM

(Pl. X, figs. 57, 58, 59, Text figs. 11 and 12).

Excretion is performed in three different parts of the body.

(i) by the Antennary glands and their connections.
(ii) by the Ferment cells of the digestive gland.
(iii) by the Branchial excretory organ.

### (i) The Antennary Glands and Connections.

These form a complicated system of organs at each side of the body. The right and left sides, which are similar to one another are absolutely separate, although in certain places the two parts are in very close contact. This excretory organ is a coelomoduct*, and may be divided into three portions on each side. The first part, or the **antennary gland** ("green gland," "rein antennarie"), is situated in the cephalic region immediately behind the eye socket. It is a small spongy mass of a

* Goodrich. Various papers in *Q.J.M.S.*, Vols. XXXVII-XLV.

light green colour, having a triangular shape when viewed from above. At its posterior and inner corner it is connected with the second portion—the **bladder** ("vessie," Marchal; "nephro-peritoneal sac," Weldon). This is an extensive thin-walled sac having several large branches. It is easily made out because of the dark brown colour of its walls. Immediately in front of the antennary gland the main portion of the bladder is connected ventrally with the third part—the **ureter.** This is a spacious tube leading downwards and opening to the exterior beneath the *operculum*, which is situated on the ventral side of the basal portion of the second antenna.

(1) The Antennary Gland (Pl. X, figs. 58, 59, Text fig. 11) is made up of two portions. On the dorsal side is a small vesicle—the **end sac** ["saccule," Marchal] (fig. 58, *end. s.*, Text fig. 11, *e.s.*). From the floor of the end sac are given off numerous blind prolongations, which may either be simple or branched. The epithelium lining the end sac (*e.es.*) is composed of flattened irregularly-shaped cells, some of which project more than others into the cavity of the end sac. Many of these cells contain small yellow oil globules. Marchal speaks of the epithelium of the end sac in Maia as being columnar, but in Cancer it has a decidedly squamous appearance. Marchal also states that the walls of the end sac are more than one cell thick in places. This does not appear to be the case in Cancer. The cells of the end-sac epithelium do not stain so deeply as the epithelial cells of the lower part of the antennary gland.

The ventral portion of the antennary gland is much larger than the dorsal end sac. In sections this lower portion is seen to have a very complicated structure, and is, therefore, known as the **Labyrinth** (fig. 58, Text fig. 11,

*Lab.*). The essential part of the labyrinth is the *Renal tube* (*tu.*), the cavity of which is connected in front with the end sac and behind with the bladder. The roof of the renal tube is in close contact with the floor of the end sac. It may be conceived that the lumen of the renal tube was primitively quite simple, so that in such a condition of things the ventral part of the antennary gland would show none of the complicated structure which we designate the labyrinth. The complexity has been produced in two ways. As already mentioned, the floor of the end sac sends downwards numerous branched tubes, the cavity of each tube being connected with that of the end sac, and its walls being lined by the squamous epithelium typical of the end sac. The floor of the end sac is closely applied to the roof of the renal tube, so that these prolongations push before them the epithelium of the renal tube, at the same time breaking up its lumen. Invaginations also appear in the ventral and lateral walls of the renal tube, giving rise to partitions across the lumen of the tube known as *trabeculae*. These ventral and lateral ingrowths are not caused by the extension of the end sac. In sections the dorsal ingrowths of the end sac can always be distinguished from the ventral ingrowths by the fact that the former appear to be lined by two rows of epithelial cells—the squamous epithelium of the end sac, carrying before it the epithelium of the renal tube, the two only being separated by a narrow blood sinus. The ventral ingrowths are only lined by the epithelium of the renal tube, and enclose portions of connective tissue which have been drawn in from tissue surrounding the gland. The epithelium of the renal tube (fig. 59, *e. tu.*) is distinctly columnar, and the protoplasm has a finely striated appearance. The cells are lined by a thin border, which is generally described as a cuticle.

In sections through the antennary gland the following structures may, therefore, be made out:—

*Dorsal.* (*a*) The main portion of the end sac. This is a simple cavity lined by squamous epithelium, the cells of which do not take the stain well.

*Ventral.* The labyrinth made up of the following parts:—

(*b*) Numerous small spaces with an inner lining of squamous epithelium (ventral prolongation of the end sac), and an outer lining of deeply stained columnar epithelium.

(*c*) Irregular spaces surrounded by columnar epithelium which is deeply stained. On the side facing the lumen the cells are lined by a fine border. These are portions of the renal tube.

(*d*) Small spaces lined by the renal tube epithelium. In the spaces are connective tissue cells and blood. These are the trabecular ingrowths. In some parts the epithelium of the trabeculae fuses with the epithelium of the roof of the renal tube, so that the blood sinus passes right through the labyrinth.

(*e*) Between the epithelium of (*b*) and (*c*) may be made out small blood sinuses.

(2) The bladder (Fig. 57, Text figs. 11, 12) is extensive and complicated. It is a thin-walled sac readily made out on account of its deep brown colour.

The Main Vesicle is situated above the antennary gland, and its cavity is continuous with that of the renal tube at the inner and posterior end of the antennary gland In front of the gland it is connected with the ureter. From the main vesicle are given off the following lobes:—

(*a*) at the anterior end—Epigastric lobe, Progastric lobe, Antero-lateral lobe, Cerebral lobe.

(β) at the posterior end—Hepatic lobe, Supra-hepatic lobe, Paragastric lobe, Oesophageal lobe.

The **Main Vesicle** ["sac vésical," Marchal] (*M.V.*) is situated below the anterior and outer corner of the stomach and above the antennary gland, with which it is connected at the posterior of the latter. On its ventral side the main vesicle is connected with the ureter immediately in front of the antennary gland.

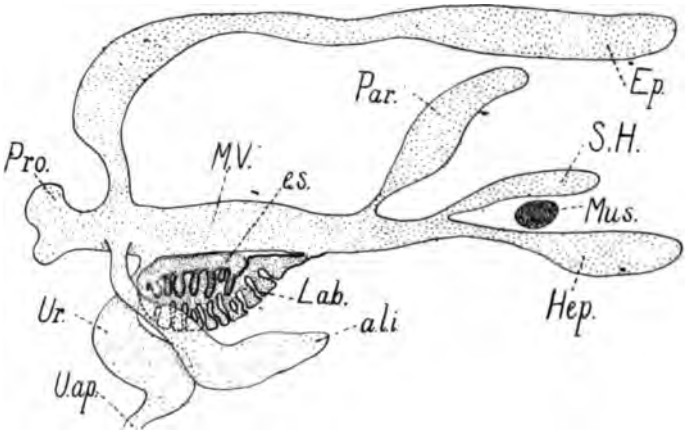



FIG. 11.—Diagrammatic longitudinal section of the excretory system.

*Ep.* = Epigastric lobe.
*Pro.* = Progastric ,,
*Par.* = Paragastric ,,
*S.H.* = Supra-hepatic ,,
*Hep.* = Hepatic ,,
*a.l.i.* = Inner part of antero-lateral lobe.
*M.V.* = Main vesicle.
*Mus.* = External adductor muscle of mandible.
*e.s.* = End sac.
*Lab.* = Labyrinth.
*Ur.* = Ureter.
*U. ap.* = External aperture of ureter.

The **Epigastric lobe** (Fig. 57, *e. lb.*, Text fig. 11, *Ep.*) is the most obvious part of the bladder when dissecting the crab from above. It arises from the anterior end of the Main Vesicle. It passes forwards and upwards along the front wall of the fore-gut and turns back along the dorsal wall, extending as far back as the

pyloric region. It is clearly separated in the middle line from the corresponding lobe of the other side. It is broad anteriorly, and becomes narrower and more irregular in shape towards the posterior end. The outer part of the broad anterior portion is slightly reflected down the side wall of the fore-gut and comes into contact with the paragastric lobe.

The **Progastric lobe** (Fig. 57, *p. lb.*, Text fig. 11, *Pro.*), is, strictly speaking, part of the Epigastric lobe. It is situated close to the connection between the Main Vesicle and the Epigastric lobe. It is on the inner side of the latter, and is closely applied to the front wall of the stomach. The lobes of each side come into very close contact in the median line, and it is only by very careful dissection that they are seen to be separate.

The **Antero-lateral lobe** ["lobe du muscle adducteur," Marchal] (Fig. 57, *a. lb.*, Text fig. 11, *a. l. i.*) arises from the anterior and outer corner of the Main Vesicle. It consists of two parts:—

(*a*) An inner lobe (Text fig. 12, B, *a. l. i.*), which passes inwards beneath the antennary gland.

(*b*) An outer lobe (Text fig. 12, B, *a. l. o.*), which passes outwards beneath the digestive gland as far as the origin of the outer adductor muscle of the mandible.

The **Cerebral lobe** (fig. 57, *c. lob.*) arises from the anterior and inner corner of the Main Vesicle. It passes inwards above the cerebral ganglia, and almost meets the corresponding lobe of the other side.

The **Hepatic lobe** ["arriere vessie" (part), Marchal] (fig. 57, *h. lb.*, Text fig. 11, *Hep.*) arises from the posterior and outer corner of the Main Vesicle by a very narrow portion, which passes beneath the outer adductor muscle of the mandible close to its insertion on the mandibular apophysis. The main part of the lobe passes outwards

beneath the digestive gland and follows the course of the gland to its extreme outer and posterior corner. Along the outer edge of the digestive gland the lobe turns upwards and covers the outer part of the dorsal portion of the gland. Owing to its position beneath the digestive gland the hepatic lobe is not readily seen, in spite of its large size. Near the origin of this lobe from the Main Vesicle a small inner lobe is given off, which ends blindly near the posterior oesophageal lobe.

The **Supra-hepatic lobe** (fig. 57, *s. lb.*, Text fig. 11, *S. H.*) is not well developed in Cancer. It arises from the Main Vesicle on the inner side of the origin of the hepatic lobe, and passes above the digestive gland on each side of the fore-gut.

The **Paragastric lobe** (fig. 57, *g. lb.*, Text fig. 11, *Par.*) arises from the posterior end of the Main Vesicle near to the origin of the supra-hepatic lobe. Its outer side is applied to the mandibular apophysis, and on its inner side it comes into contact with the side wall of the fore-gut. It passes up the side of the latter and touches the epigastric lobe.

The **Oesophageal lobe** arises from the inner and posterior corner of the Main Vesicle. It passes inwards and divides into anterior (*as. lb.*) and posterior (*po. lb.*) portions which wrap around the oesophagus, touching the corresponding lobe of the other side in the middle line.

In sections through a young crab (width of carapace 15 mm.) the epithelium of the bladder (Pl. XII, fig. 82) consists of columnar cells 20$\mu$ long and 15$\mu$ wide. The protoplasm is denser near the outer portion of each cell, and the inner portion of the protoplasm is greatly vacuolated. In the outer region of the cell the protoplasm is arranged in longitudinal strands, which gives rise to the

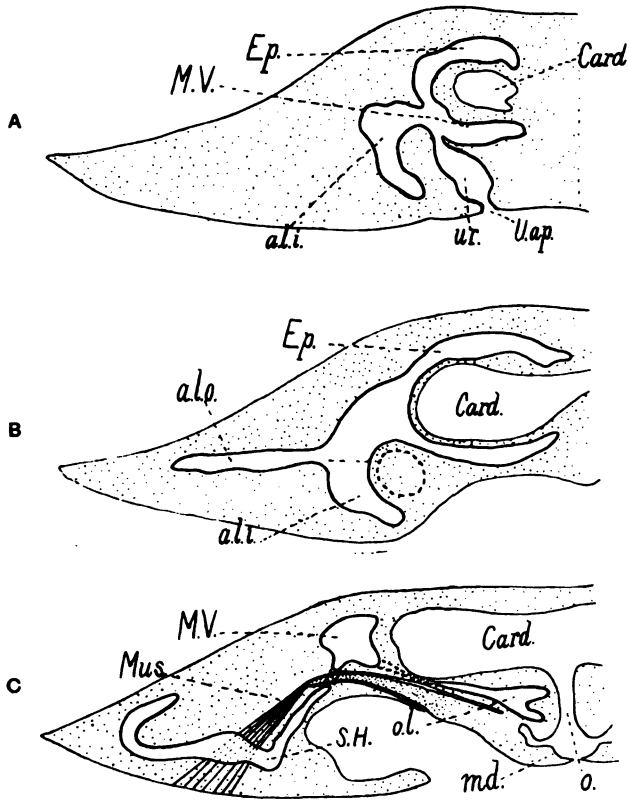



FIG. 12.—Diagrammatic transverse sections through the left half of the body to show the excretory system.

*A.* = at the level of the external excretory aperture.

*B.* = at the level of the "green gland." (The gland is shown as a dotted line.)

*C.* = at the level of the oesophagus. (For *S.H.* read *Hep.*)

*Card.* = cardiac region of the fore-gut. *o.l.* = oesophageal lobe.

*o.* = oesophagus. *md.* = mandible.

*a.l.o.* = outer portion of antero-lateral lobe.

(Other references as in Fig. 11).

striated appearance noted by Weldon and Allen. In some cases these striations are carried through to the inner region of the cell, but generally the protoplasm is divided into a deeply-stained outer portion, which exhibits the striations mentioned above, and a more lightly stained inner portion in which the strands of protoplasm are few in number, thus causing the vacuolated appearance. The nucleus of the bladder epithelial cells has a diameter of 6$\mu$, and is situated near the centre of the cells.

(3) The Ureter (Text fig. 11, 12, A, *Ur.*) is a spacious sac situated on the inner side of the antennary gland, partly in front of and partly below the gland. The connection with the main vesicle is a narrow opening immediately in front of the anterior and inner corner of the gland. The ureter passes downwards, and opens to the exterior on the ventral surface of the proximal portion of the second antenna. It is lined with epithelial cells, which are distinctly larger than those of the bladder and take the stain more distinctly.

The relation of the parts in the neighbourhood of the external orifice is of interest. The proximal region of the ventral side of the second antenna is occupied by a small, irregularly-shaped plate—the *operculum* (Pl. II, fig. 5, *op.*), which is freely movable. The movement is possible because of its connection, by means of a flexible membrane, with the surrounding hard parts. The membrane forms a pocket-like invagination around the operculum, and is deepest on the inner and posterior side, so that the movement is greatest on this side when the operculum is raised. When the operculum is elevated it is seen that the membrane is perforated by a distinct orifice on the inner and posterior side. This is the *excretory orifice*. Hence Marchal* termed the membrane

* Marchal. "Appareil excréteur des Crustacés Décapodes." *Arch. Zool. exp. et gén.*, T. X (Ser. 2), 1892.

surrounding the orifice the *excretory membrane*. He states that the excretory fluid is not ejected as the result of muscular contraction around the walls of the sac-like ureter. There are no muscles in the walls of the ureter. The outflow is of a passive character, and takes place whenever the excretory orifice is opened. Although it is probable that the operculum does not fit tightly enough to prevent the outflow of the excretory fluid, yet it is when the operculum is closed that the fluid ceases to escape. When the operculum is drawn down closely into its socket, the lips of the excretory orifice are pressed together because of the contraction of the excretory membrane. On the contrary, when the operculum is raised the membrane is extended and the orifice opens. As shown by Marchal, the movements of the operculum are under the control of two muscles—an *elevator muscle* for extending the operculum membrane, and a *depressor muscle* for drawing the operculum down into its socket.

## Mode of Excretion.

According to Marchal, the excretory fluid is not produced by diffusion across the epithelial cells of the antennary gland and bladder, but is the result of an actual breaking away of a part of each of the epithelial cells. An examination of the excretory fluid will show that there are numerous bladder-like vesicles and also cells floating in the fluid. In sections of the bladder, and also in teased preparations, one can see, as stated above, that the protoplasm is highly vacuolated on the inner side of each epithelial cell. Moreover, in some cells there is one large vacuole, or vesicle, projecting into the lumen of the bladder and surrounded by an extremely thin layer of protoplasm. In the interior of the vesicle is a fluid sometimes containing refringent

granules. Each vesicle which contains excretory fluid and excretory granules ultimately breaks free from the cell and floats away in the excretory fluid.

In addition to this method, it is highly probable that some of the excretory fluid passes through the epithelial cells into the cavity of the bladder by the ordinary process of diffusion.

The above mode of excretion is not only performed by the cells of the bladder, but also, according to Marchal, by the cells of the labyrinth, in a slightly modified manner.

As stated above, the cells of the renal tube in the labyrinth appear to be lined by a thin cuticle. Marchal states that it is *not* a cuticle, but that the appearance is due to a row of very small vacuoles lining the inner side of each epithelial cell. These vacuoles gradually increase in size, fuse together, and the single large vesicle formed is liberated into the lumen of the renal tube, in a very similar manner to the method described above in the case of the bladder.

In the cavity of the end sac the fluid contains small vesicles containing yellow oil globules. These have been excreted from the epithelial cells of the end sac, which, as mentioned above, often contain yellow oil globules.

In addition to these, Marchal states that in Maia *entire* epithelial cells break free from the walls of the end sac.

At first Marchal believed that in Maia the wall of the end sac was composed of a single layer of cells, and he expressed surprise that it was possible for cells to break away bodily from such a layer without breaking the continuity of the walls of the end sac. Finally he decided that the wall was several cells thick in certain places, and that it was from these places that the cells found in the

lumen of the end sac had broken free. Whatever may be the condition of things in Maia, there is no doubt that in Cancer the walls of the end sac are uniformly only of one cell in thickness. As in Maia, there are cells in the cavity of the end sac, and I agree with Marchal that these are epithelial cells of the end sac which have broken away. There appears to be nothing surprising that certain cells of this single layer of epithelial cells should be gradually nipped off by the activity of the surrounding cells and thus shed into the lumen of the end sac. An examination of serial sections through the end sac reveals cells in every stage of this process of shedding. This explains why certain cells of the end sac epithelium project farther into the lumen than others, as described above.

Cuénot investigated the excretory organs of Crustacea by injecting various colouring matters into the body of the living animal. He has placed these colouring matters into three groups, according to where they were eliminated.

(1) Fuchsin acid, Bismarck brown, safranin, indigo-carmine, etc.

(2) Methylene green, ammonium carminate, etc.

(3) Methylene blue.

After such injections it was found that the cells of the renal tube of the labyrinth and the cells of the bladder have a decidedly alkaline reaction and excrete the substances of the first category. The cells of the end sac, on the other hand, have an acid reaction and eliminate the substances of the second category.

By the above method of injection Cuénot discovered that in addition to the antennary gland and its connections there are two other kinds of excretory cells, viz. :— The ferment cells of the digestive gland, and the cells in the branchial septum.

Development of the Antennary Gland.

According to Waite,* who studied the development of the gland in Homarus, the end sac alone arises from the mesoderm when the embryo is only five days old, and its lumen is for a long time completely enclosed by mesodermal cells. An ectodermal ingrowth (which ultimately becomes the renal tube of the labyrinth) occurs at about the twenty-eighth day. The lumen of the end sac does not become continuous with that of the labyrinth until the embryo is nearly 300 days old. The complications in the walls of the renal tube to form the labyrinth do not occur until the third larval stage. The bladder is formed by a dorsal outgrowth of the ectodermal tube. Therefore, only the cavity of the end sac represents part of the original coelom. The renal tube of the labyrinth, the bladder and the ureter are all ectodermal in origin. Although the development of the green gland in the Brachyura has not been investigated, there is no reason to believe that it presents any striking differences from that of the Macrura.

(ii) Ferment Cells of the Digestive Gland.

Part of the contents of the ferment cells are of an excretory nature, and when the contents of these cells pass down the digestive tubules into the mid-gut the excretory products are separated away and are carried to the exterior along with the faeces. The ferment cells of the digestive gland take up methylene blue when this colouring matter is injected into the body of the living animal. The large coloured mass inside each ferment cell is coloured light blue. Inside this mass there are small bodies, which take a dark blue stain. According to Cuénot, in five days after the experiment the blue

* Waite. *Bull. Mus. Harv.*, Vol. XXXV, No. 7 (1899).

stain will pass out into the lumen of the tubule and thence to the alimentary canal, where it is got rid of along with the excrement.

(iii) Branchial Excretory Organ.

This is found in the gills in that portion of the tissue situated between the afferent and efferent branchial veins. According to Cuénot, the excretory cells are continued along the sides of the branchio-cardiac veins When the crab is subject to Cuénot's system of injection, it is found that the cells of the branchial excretory organ act like the cells of the end sac They have an acid reaction and eliminate substances of the second category.

## NERVOUS SYSTEM.

The nervous system of the Brachyura (*Carcinus maenas*) has been investigated in detail by Bethe.* It is proposed to give here only a short account of the nervous system of Cancer.

The nervous system may be described briefly as consisting of two main nerve masses—the fused pre-oral cerebral ganglia and the fused ganglia of the post-oral region. The two are connected by a pair of commissures which pass round the oesophagus. With the cerebral ganglia are connected the nerves supplying the eye, antennules and antennae. All the post-oral appendages and somites are innervated from the posterior nerve mass which lies in the thorax. At each side of the oesophagus there is a ganglion on the commissure, from which arises the stomatogastric nerves supplying the fore-gut.

The brain is the centre of co-ordinated movement, and each ganglion of the ventral nerve mass is the reflex centre for the appendage which it supplies.

* Bethe. *Arch. f. Mikr. Anat.*, Bd. XLIV (1895), pp. 579-622; Bd. L (1897), pp. 460-546, 589-639; Bd. LI (1898), pp. 382-452.

## The Brain.

The Brain (cerebral ganglia, *c.g.*) is situated above the anterior end of the epistoma. It is roughly rectangular when viewed from above, and is formed of a complex mass of nerve cells and fibres. The anterior half of the brain is connected with the nerve fibres supplying the eye and optic peduncle. From the posterior half arise the nerves innervating the antennules, antennae, the sense organs of the antennules, and also the nerves supplying the integument. The nerve fibres from the different parts become aggregated in the brain in definite masses or *neuropiles* ("Punktsubstanz," Leydig). Between the neuropiles there are numerous nerve cells more or less closely packed. The main neuropiles are as follows:—

Connected with the optic fibres. The *antero-superior*, *median* and *posterior optic neuropiles*, all situated in the anterior half of the brain. Also the *inferior optic neuropile* extending below the others.

Connected with the oculomotor fibres. The paired *lateral oculomotor neuropiles* situated on the outer side of the optic neuropiles, and also a *median oculomotor neuropile* lying in the middle line behind the optic neuropiles.

Connected with the first antenna (antennule). The *median neuropile of the first antenna* situated in the middle line below the median oculomotor neuropile. The *lateral neuropiles of the first antenna* situated ventrally at each side, behind the inferior optic neuropiles.

Connected with the second antenna. There are three neuropiles situated at each side of the posterior region of the brain, viz., the *median*, *posterior* and *lateral neuropiles of the second antenna.*

Connected with the tegumentary nerves. The

*superior and inferior tegumentary neuropiles* situated in the posterior region of the brain, slightly anterior to the neuropiles of the second antenna.

At each side of the brain there is a globular mass of radiating fibres lying between the oculomotor and the tegumentary nerves. This is the *globulus*. There is a tract of nerve fibres extending from the globulus to the median optic neuropile. It is probable that some of the fibres of the otocyst nerve arise from the globulus.

The chief groups of nerve cells in the brain are as follows:—

The *supero-median* cells are on the inner side of the antero-dorsal region of the brain.

The *infero-median* cells are situated on the ventral side of the posterior part of the brain near the median line.

The *supero-lateral* cells are situated dorsally on the inner and anterior side of the globulus.

The *infero-lateral* cells extend along the inner side of the globulus on the ventral side of the brain.

The *anterior globular* cells are situated ventrally on the inner and anterior side of the globulus.

The *posterior globular* cells lie above and behind the globulus at its outer and posterior side.

The following nerves are connected with the brain (fig. 68):—

**Optic nerve** (*o. n.*). One pair. Each arises from the dorsal side of the brain at its anterior corner. The fibres are continuous with those of the various optic neuropiles. It runs outward and forward at an angle of 45° with the longitudinal axis, and passes into the distal part of the optic peduncle, where the latter articulates with the proximal part of the peduncle. In the swollen part of the peduncle the nerve becomes enlarged to form the optic

ganglion (fig. 69, *o.g.*). From this ganglion nerve fibres are given off, which pass through the basement membrane and innervate the various ommatidia of the eye (see figs. 69, 70).

**Oculomotor nerve** (*om. n.*). One pair. These arise from the brain immediately behind the optic nerve. Each passes outward behind the optic nerve, and supplies the optic peduncle and the muscles connected with it.

**Antennulary nerve** ($a.^1 n.$). One pair. At each side this nerve appears to be single, but it is composed of two different kinds of fibres, having different functions and arising from different centres in the brain. For this reason the two nerves should be described separately, as in the case of the optic and oculomotor nerves. The main branch innervates the antennule, and is connected in the brain with the fibrils of the median neuropiles. The fibres innervating the olfactory and tactile setae are probably connected with the lateral neuropiles. The otocyst branch is connected with the lateral neuropiles, and also with the globulus. It passes out from the brain together with the fibres of the main branch, but the two kinds soon separate and those innervating the otocyst pass outwards, and the fibres are connected with ganglion cells at the base of the otocyst setae. The antennulary nerve arises from the middle of the ventral surface of the brain, but in Cancer it apparently leaves the brain near the anterior end.

**Tegumentary nerve** (*t. n.*). One pair of broad nerves, which leave the brain near the postero-lateral corner. Each passes outwards almost at right angles to the longitudinal axis, and divides into two main branches. The anterior branch supplies the integument in region of the rostrum. The outward branch sweeps backwards and outwards, giving off small branches to the integument.

**Antennary nerve** (*a.*$^2$ *n.*). One pair of small nerves, which arise from the ventral side of the brain immediately behind the tegumentary nerves. They are connected with the fibres of the neuropiles of the second antenna. Immediately on leaving the brain each passes beneath the tegumentary nerve and enters the muscle chamber of the second antenna.

The **commissures** (*Com.*). One pair of rather large nerves, which arise from the posterior side of the brain. They pass posteriorly on each side of the oesophagus, and are connected with the ventral nerve mass in the thorax. At each side of the oesophagus there is a *paroesophageal ganglion* (*p. g.*), and behind the oesophagus the two commissures communicate by means of a transverse *post-oesophageal connective* (*n. po.*). From the paroesophageal ganglia arise the stomatogastric nerves, and immediately behind the ganglion there is a small nerve (*n. m.*) supplying the muscles of the mandibles.

## Ventral Nerve Mass.

The ventral nerve mass (*t. g.*) is situated above the sternal artery in the third and fourth thoracic somites. It is partly supported by the median plate of the endophragmal system. It contains nerve elements representing the post-oral cephalothoracic ganglia and the abdominal ganglia. It is not possible to make out all these ganglia from dissections, but they may be distinguished in stained preparations and in sections. Slightly behind the centre of this fused ganglionic mass is a foramen (*n. f.*), through which passes the descending artery.

At its anterior end, where it is connected with the commissure, the ventral nerve mass is narrower than in its posterior portion. In this anterior portion it is

possible to make out, in suitable preparations, evidences of six pairs of ganglia belonging to the last three cephalic and the first three thoracic somites. Behind this region five pairs of larger ganglia may be distinguished more readily. From these arise the nerves supplying the five pairs of pereiopods and the last five thoracic somites. Between the last two ganglia is a median swelling, which is composed of the six ganglia belonging to the abdominal somites.

The following nerves arise from the ventral nerve mass:—

**First nerve** (*n.* 1). One pair. Each arises close to the connections between the commissure and the ventral nerve mass. It contains fibres from the first three ganglia of the nerve mass. It passes forwards parallel to the commissure and divides into three branches, passing to the mandible, first maxilla and second maxilla respectively.

**Second nerve** (*n.* 2). One pair. Each arises behind the first nerve, and its fibres are connected with the cells of the fourth ganglion of the nerve mass. It passes forward and slightly outward, and supplies the various parts of the first maxillipede.

**Nerves 3-9** (*n.* 3-*n.* 9). These are all paired, and are connected with the fifth and following ganglia of the ventral mass. Each nerve supplies the appendage of its own somite, and its course is very similar to that of the second nerve. Nerves 5-9, however, are larger than the others, and the posterior nerves pass outwards and backwards.

**Abdominal nerve** (*n. ab.*). This is a median nerve, which passes backward in the median line. It arises from the fused abdominal ganglia at the posterior end of the ventral nerve mass, and contains nerve fibres from all the

abdominal ganglia. It passes backward along the median line of the "sella turcica" and along the ventral region of the abdomen. Small nerves are given off to each somite of the abdomen.

According to Jolyet and Viallanes,* the centres of the moderator and accelerator nerves of the heart are in the anterior part of the ventral nerve mass. The cardiac nerve of the Macrura does not appear to be present in the crabs.

### The Stomatogastric System.

This consists mainly of nerves arising from the paroesophageal ganglia. These nerves fuse to form the stomatogastric nerve, which supplies the anterior and dorsal regions of the fore-gut. There is also the postero-lateral nerve arising behind each paroesophageal ganglion.

There are two main nerves arising from each paroesophageal ganglion. These pass below the commissure, and, passing forward, they fuse with each other and with the similar nerves of the other side to form the main stomatogastric nerve. The *ventral* nerve (*st. i.*) arises from the outer side of the ganglion, and immediately passes below the lateral dilator muscle of the oesophagus, to which it gives small branches. It passes below the commissure and innervates the anterior dilator muscles of the oesophagus. It then turns upward and fuses with the similar nerve of the other side and with the *dorsal* nerve. The latter nerve (*st. s.*) arises from the anterior and outer side of the paroesophageal ganglion. It passes immediately below the commissure, and gives off a small nerve to the anterior walls of the oesophagus. In the median line it fuses with the corresponding nerve of the opposite side, and also with the ventral nerve.

The **stomatogastric nerve** (*st. n.*) is formed by the

* Jolyet et Viallanes. *Comptes Rendus*, CXIV (1892), p. 189.

fusion of the two ventral and dorsal roots, as described above. It passes up the anterior wall of the cardiac fore-gut as a median nerve. About half way along this wall the nerve enlarges to form the *stomatogastric ganglion* (*st. g.*). From this point the nerve proceeds backward along the dorsal side of the fore-gut, and almost immediately gives off two large branches—the **lateral gastric nerves** (*l. g. n.*). Each lateral gastric nerve passes over the anterior cardiac muscle, which it innervates, and gives rise to a nerve plexus in the dorsal walls of the cardiac fore-gut. Both nerves also give rise to an internal branch, which passes inwards and joins again with the stomatogastric to form a large ganglion. Behind this ganglion the stomatogastric nerve bifurcates. Each branch, which is known as the **posterior gastric nerve** (*p. g. n.*), passes backward to the pyloric fore-gut. Here the two nerves join again, thus forming a ring. From the posterior end of this ring three nerves are given off—one to the hind-gut (*n. i.*), one to the digestive gland (*n. l.*) and one to the integument (*n. t.*). The muscles in this region of the fore-gut are also innervated from the posterior gastric nerves.

The **postero-lateral nerve** (*p. n.*) of each side arises from the inner side of the commissure, immediately behind the paroesophageal ganglion. It passes backward, and innervates the posterior dilator muscle of the oesophagus. It then passes upward along the posterior wall of the fore-gut, and supplies the muscles in this region.

## Sense Organs.

### The Eye.

Each eye is situated at the distal extremity of the long optic peduncle. The peduncle is clearly divided into two portions:—(1) A long narrow proximal part, which

meets the peduncle of the other side in the median line above the first cephalic sternum. This proximal portion is not seen from the exterior. (2) A shorter and broader distal portion, which is the part seen from the exterior. The two parts are separated by a region of soft chitin, which allows of considerable movement between the two parts. At the distal extremity of the peduncle is a small black area—the *cornea*—which defines the external surface of the eye. The cornea would be almost circular were it not for the presence of two small tubercles which invade the dorsal border of the black area, and thus give it a somewhat irregular shape. The cornea is composed of a thin layer of chitin, which is continuous with the thick, strongly calcified integument covering the remainder of the distal part of the peduncle.

The thick calcified integument has the usual layer of epidermis beneath, resting upon a basement membrane. In the region of the eye, the cellular layer on the inner side of the cornea is extremely thick, and is known as the *ommateum*. On the inner side of the ommateum is a well-defined basement membrane, which is continuous with that of the ordinary epidermis. The ommateum, therefore, may be regarded as a differentiation of the epidermis, with which it is continuous.

An examination of the surface of the cornea reveals the presence of numerous small hexagonal facets. Vertical sections through the eye show that this sub-division of the cornea is not merely superficial, but is continued through to the inner side of the chitinous layer. The cornea may, therefore, be said to be composed of numerous hexagonal prisms, which are packed closely together. On the inner side of the cornea the ommateum is divided into numerous elements, which correspond in number and position to the corneal facets. Each element of the ommateum is known

as an ommatidium and fits below a corneal facet, and extends from the cornea to the basement membrane. All the ommatidia have the same essential structure.

*Structure of an ommatidium.*

Each ommatidium may be conveniently divided into proximal and distal regions. The outer parts of both these regions are defined by the presence of pigment (fig. 69, *pg. i.*, *pg. o.*).

Underlying the cornea is the flattened corneagen. Below this are the vitrellar cells, the distal region of which enclose the crystalline cone. The vitrellae are surrounded by pigment cells, which are densest on a level with the proximal region of the crystalline cone. At the proximal end of the vitrellae are the pigmented retinulae which surround the rhabdome. The retinulae are in contact with the nerve fibres from the optic ganglion, and the proximal end of the rhabdome is in contact with the basement membrane.

The **corneagen** ["corneal hypodermis," Parker] (fig. 70, *corn.*) lies immediately below the cornea, which is a product of the corneagen cells. It consits of two flattened tile-like cells.

The **vitrellae** ["cone cells," Parker] (*vit.*) lie immediately below the corneagen. Transverse sections show that there are four vitrellae in each ommatidium. Their distal extremities are applied to the base of the corneagen. Passing inward the cells become narrower. Distally they enclose the crystalline cone, which is secreted by these cells. Surrounding the vitrellae are two **pigment cells** (*pg. c.*), which are continued inward as fine processes and eventually come into contact with the retinulae. (Fig. 72 is a section through the vitrellae of a single ommatidium, and shows that there are four vitrellar

cells surrounded by two pigment cells.) Between the vitrellae and the pigment cells there are intercellular spaces, which are larger at the proximal end of the vitrellae.

The **retinulae** (*ret.*) are seven pigment cells which surround the rhabdome, and extend from the proximal portions of the vitrellae to the basement membrane. Distally each retinula ends in a rounded knob, which contains a nucleus (fig. 71 shows the disposition of the retinulae around the rhabdome). At their distal ends the retinulae are extremely large, and surround the rhabdome in this region so as to completely hide it. The concentration of the pigment in this region gives rise to a well-marked pigment band (fig. 69, *pg. i.*). Proximally the retinulae are not so large, and the rhabdome can be seen quite distinctly between them. The rhabdome has a peculiarly striated appearance, which is caused by the arrangement of the pigment granules of the retinulae. The optic nerve fibres pass into the retinular cells, so that it is this part of the eye which is sensitive to light.

The **rhabdome** (*rhab.*) is a rod-like structure in the centre of the retinulae. According to Watase,* the rhabdome is a chitinous structure produced as a secretion from the retinulae. Parker† states that transverse sections show that the rhabdome is composed of four parallel rods, and he further affirms that these four rods are the inner extremities of the four vitrellae (cone cells).

The *optic nerve fibres* perforate the basement membrane and end in the retinulae.

Each ommatidium, therefore, may be said to consist

* Watase, S. "On the Morphology of the Compound Eyes of Arthropods," *Q. J. M. S.*, Vol. XXXI, p. 143.

† Parker, G. H. "The Histology and Development of the Eye in the Lobster," *Bull. Mus. Comp. Zool. Harv.*, Vol. XX, No. 1.

—— "The Compound Eyes in Crustaceans," *loc. cit.*, Vol. XXI, No. 2.

of a series of cells which on their outer side receive and concentrate the rays of light. These are transmitted to the retinulae by means of the transparent vitrellae. The retinulae are connected with the nerve fibres, and are, therefore, the important part of the eye. Each ommatidium is surrounded by a layer of pigment, so that the sensitive retinulae are situated at the bottom of a tube, which is completely separated from the tubes of the other ommatidia because of the presence of the pigment. Therefore, the retinulae of an ommatidium can only receive light through the small corneal facet at the distal extremity of the particular ommatidium.

The **cornea** (*cn.*) is composed of three layers. On the outside is a thin structureless layer—the *cuticle* (*cut.*). Beneath this is an outer *pigmented layer* (*pig. l.*), to which the colour of the cornea is due. Below the pigment layer is the *deeper layer*. Both inner layers exhibit longitudinal striations.

According to Watase, the corneagen, vitrellae and retinulae are all modified epidermal cells, which, in the case of the vitrellae and retinulae, have grown inward. The cornea is a chitinous secretion of the corneagen. The crystalline cone is primarily a chitinous secretion of the vitrellae, and the rhabdome is a chitinous rod secreted by the cells of the retinulae.

### The otocyst.

The otocyst is found in the basal segment of the antennule. It is a sac lined with a layer of chitin, which is continuous with the outer chitinous integument. In the megalopa stage and in the young crabs the otocyst is open to the exterior, and in these stages otoliths are present in the sac. In large crabs, however, there are no otoliths, and the sac is completely closed except

immediately after ecdysis, when the otocyst is connected with the exterior by means of a transverse slit on the dorsal side of the basal segment of the antennule. This slit is quite obvious in the hard crab. The walls of the sac project into the lumen at three places—(1) in the postero-lateral wall (2) in the posterior wall, and (3) the anterior part of the floor.

There are three kinds of setae situated on the walls of the otocyst and projecting into the lumen.

The **hooked setae** ["Hakenhaare," Hensen] (Pl. XI, fig. 75) are found on the convex portion of the posterior wall of the otocyst. These setae are characterised by having the distal extremity inclined at a considerable angle to the proximal portion, sometimes as much as 90°. The distal portion of the shaft has fine barbs arising from it. The base of the shaft is sunk into a socket-like depression. The total length of the hook hairs is about 55$\mu$.

The **thread setae** ["Fadenhaare," Hensen] are found on the anterior part of the floor. They are the largest setae present in the otocyst, and are about six times as long as the hook hairs. There are well-defined barbs arising from the shaft. The base of each seta lies in a cup-shaped depression of the chitinous wall.

The **grouped setae** ['Gruppenhaare," Hensen] (fig. 76) are situated on the lateral walls of the otocyst, below the closed entrance of the sac. They are about 140$\mu$ in length, and have blunt shafts. There are no barbs present.

The three kinds of setae are innervated from the otocyst nerve, and according to Prentiss* there is one nerve element for each seta. The same author states that

* Prentiss, C. W. "The Otocyst of Decapod Crustacea: its structure, development, and functions," *Bull. Mus. Comp. Zool. Harv.*, Vol. XXXVI, No. 7.

the otocyst does not become functional until the megalopa stage.

Hensen and the early observers believed that the otocyst was an auditory organ. Hensen found that the "auditory" setae were individually sensitive to sound vibrations of different frequency, and concluded that in the lobster the auditory organ had a range of three octaves.

Kreidl was the first to deny that the otocysts possessed an auditory function. He substituted iron filings for the otoliths, and the experiments led him to believe that this organ served the function of equilibration.

Bethe, while accepting Kreidl's results, did not reject the idea that the otocyst was also an auditory organ.

The researches of Prentiss led him to believe that the otocyst was a static organ solely. It is probable that in the Brachyura the hooked setae and grouped setae have lost most of their functional activity owing to the absence of otoliths. The thread setae are, undoubtedly, the most important sensory organs of the otocyst. (For a further discussion of this subject the reader is referred to the paper by Prentiss.)

The sensory setae of Cancer are of two kinds.

The **tactile setae** may be present in various parts of the body. They are found on the antennules and antennae, and on most of the appendages. The setae of the otocysts are probably modified tactile setae. They are characterised by having a long tapering shaft which bears barbs, and each seta is innervated by a single nerve fibre and a single nerve cell.

The **olfactory setae** (fig. 74) are short and blunt, and are much more firmly attached to the integument than the tactile setae. Each seta is divided into proximal and

distal portions by a transverse suture. At the distal end the seta is either perforated or the membranous covering is extremely thin. The olfactory setae differ from the tactile setae in having numerous nerve elements for each seta. They are present on the exopodite of the antennule on the side opposite to the long setae. They are extremely small, and there are only one or two on each ring of the exopodite. On the endopodite of the antennule there are also a few small setae on the dorsal side of each ring, which have the appearance of olfactory setae. The gustatory setae present in the region of the mouth are modified olfactory setae.

## REPRODUCTIVE ORGANS

### (Plate XII).

### 1. Male (fig. 78).

The abdomen is much narrower than in the female, and the third, fourth and fifth abdominal somites are fused together. Abdominal appendages are present only on the first and second abdominal somites, and these are modified to form copulatory organs. The external genital apertures are paired, and each is situated at the tip of a membranous papilla on the ventral side of the coxopodite of the last walking leg. The thoracic sterna are deeply concave, in order to receive the closely-applied abdomen. The locking apparatus of the male abdomen is much better developed than in the female. The dorsal side of the carapace is much flatter in the male than in the female. As Williamson has pointed out, the lobed antero-lateral border of the carapace is slightly turned up in mature males. The chela of the mature male are larger than those of mature females of the same size.

The two abdominal appendages of each side form a

single copulatory organ (see fig. 16). The anterior appendage (*p.* 1) is tubular, and into the tube the posterior rod-like appendage (*p.* 2) is inserted during copulation. The copulatory organ of each side is introduced into one of the vulvae of the females during fertilisation. The genital papillae of the male are too short to reach the vulvae, and the abdominal appendages have become modified to form sexual organs in consequence of this. During copulation each genital papilla fits into the base of the tubular appendage and the spermatophores are poured into the tube. The rod-like second appendage is constantly working up and down the tube, and thus forces the male sexual products into the spermatheca of the female.

The **testes** (*test.*) are paired and symmetrical, and the two halves are connected immediately behind the fore-gut. Each testis is a compact lobulated organ situated in the antero-lateral region of the cephalothorax. It is superficial in position, and lies immediately below the dermis and above the digestive gland. The size and shape of the testis varies considerably according to the condition of the animal. In immature crabs it may be extremely small, but in the mature specimens the testis is massive and lobulated, and may cover almost the whole of the digestive gland. Its blood supply is obtained from the large spermatic branch of the lateral artery. At its inner extremity, near the cardiac fore-gut, each testis is connected with the vas deferens (*v. d.*). The main part of the testis gives off a posterior branch which passes backward beneath the vas deferens alongside the mid-gut caecum. Above the mid-gut this prolongation turns inward and joins with the similar portion from the other side to form a bridge behind the pyloric fore-gut.

The *vasa deferentia* are a pair of long convoluted

tubes passing backward from the testes to the posterior region of the thorax, where each opens to the exterior on the coxopodite of the last walking leg.

In a mature crab the course of each of the vasa deferentia is as follows:—Where it arises from the inner portion of the main lobe of the testis the vas deferens is an extremely convoluted and narrow tube. As it sweeps round the outer side of the cardiac stomach the tube grows broader and the convolutions become less complicated, so that in this region the course of the vas deferens may be traced without much difficulty. At the level of the pyloric fore-gut the duct turns suddenly inwards and covers the lateral walls of this region of the alimentary canal. From this point the vas deferens passes backward as a white convoluted tube above the hind-gut and below the pericardium. The maximum width is attained below the anterior region of the heart. Behind this point the duct gradually becomes narrower, and is then known as the *ejaculatory duct* (*e. d.*). At the posterior end of the pericardium the duct dips downward through the foramen on the outer side of the "sella turcica." It then passes behind the dorsal extensor muscle of the coxa of the last walking leg and in front of the extensor muscle of the basi-ischium of the same appendage. Below the latter muscle it passes beneath the flexor of the basi-ischium, and opens to the exterior at the end of a soft papilla situated on the ventral surface of the coxa of the last walking leg.

In sections through the testis the gland is seen to be composed of numerous follicles which are closely packed together. Each follicle is lined by epithelial cells which surround a central cavity, and this cavity is continuous with that of the vas deferens. In an early stage the cells of the follicles are not differentiated and are quite small.

Eventually some of these become spermatoblasts and increase greatly in size. Each spermatoblast gives rise to a large number of spermatozoa. In sections through a mature testis it is difficult to distinguish the follicles, as the cavities of the latter become almost obliterated by the growth of the spermatoblasts. When the spermatozoa are ripe they break free and are carried down into the vas deferens. Here they become collected together in small groups, and each group becomes surrounded by a capsule to form a *spermatophore*.

The spermatozoa (fig. 81) are non-motile. They consist of a central dark portion containing a nucleus and an outer clear margin. In side view the clear margin is seen to be much thinner than the central part of the cell, and has the appearance shown in fig. 81. The diameter of the cell is about $6\mu$.

The presence of the spermatophores gives rise to the white appearance so characteristic of the vasa deferentia of mature male crabs. In small immature crabs the vas deferens is narrow and almost transparent, due to the absence of spermatophores. As pointed out by Williamson, "the condition of maturity in the male is the presence of ripe male elements in the vas deferens." It is probable that most male crabs above $4\frac{1}{8}$ inches in width are mature, although Williamson has given instances of male crabs attaining maturity at a much smaller size.

### 2. Female (fig. 77).

The abdomen is broad, and all the somites are freely movable. There is one pair of appendages on each of the second, third, fourth and fifth somites. After the ova are spawned they are attached to the endopodite setae of the abdominal appendages. The external genital apertures

are a pair of large openings situated on the sternum of the sixth thoracic somite. The thoracic sterna are not so concave as those of the male, and the abdomen is not so closely applied to the thorax. The abdominal locking apparatus is poorly developed. The dorsal side of the carapace is well arched in the mature females, and the antero-lateral border of the carapace is not upturned as in the males.

The **ovaries** (*ov.*) are paired, and lie in a similar position to the male reproductive organs. There is, however, a considerable posterior prolongation of each ovary. As in the male, the two antero-lateral portions are connected behind the pyloric fore-gut by a strand of gonadial tissue, which forms a bridge over the mid-gut. Behind this transverse connection each ovary is prolonged backward as a narrow strip, which extends to the extreme posterior end of the thorax. At the posterior extremity the two prolongations fuse together in mature specimens. These backward extensions of the ovaries occupy a similar position to the vasa deferentia of the male; that is to say, they lie above the hind-gut and below the pericardium. Beneath the anterior end of the latter each posterior branch is connected on its outer side with a large sac, the *spermatheca** (*spt.*). Each spermatheca is continued into a short *oviduct* (*ovd.*), which opens to the exterior by means of the vulva on the sternum of the sixth thoracic somite.

The condition of the ova in the ovary naturally depends upon the degree of maturity attained by the gonads. The immature gonads are small and pale, and no evidence of the presence of eggs can be detected by the naked eye. The mature gonads, however, fill almost the

* In young crabs the spermatheca is extremely small, and can only be made out with difficulty.

whole of the dorsal side of the cephalothorax. They are of an orange-red colour, and the separate eggs can be readily distinguished. The red colour is due to the presence of the food-yolk. The yolk granules form the main part of the mature ovum (fig. 79). With regard to the condition of the ovaries between two processes of ecdysis, the reader is referred to the section on Bionomics.

Copulation takes place immediately after the female has cast, and while it is still in a soft condition. Apparently the spermatozoa burst free from the spermatophores as soon as they leave the vas deferens. In the spermatheca only free spermatozoa are found. After copulation the cells lining the spermatheca secrete a fluid which fills the cavity of the oviduct. This secretion hardens upon contact with the sea water, and thus the oviducts become effectively plugged, and the contents of the spermatheca cannot escape. It is a remarkable fact that the spermatozoa remain inside the spermatheca for many months before they fertilise the ova.

The eggs are spawned in the winter. Upon reaching the exterior, each egg is probably surrounded by two membranes—an inner vitelline membrane and an outer chorion. Between the two is a perivitelline space, which, according to Williamson, contains a fluid possessing adhesive properties. The eggs become attached to the endopodite setae of the abdominal appendages. The interesting question regarding the mode of attachment of the eggs to the endopodite setae is not yet conclusively settled. Some of the early observers believed that a sticky substance was secreted around the eggs as they were being shed. This, however, would not explain why the eggs become attached only to the endopodite setae. Herrick's* explanation is that the tegumentary glands of

* Herrick. "The American Lobster," *Bull. U.S. Fish Com.*, 1895.

the endopodites of the pleopods secrete an adhesive fluid. Williamson* gives a detailed explanation of the method of attachment. He suggests that the endopoditic seta penetrates the chorion of the egg in two places, and thus the egg becomes skewered on the seta. The piercing of the chorion liberates the adhesive perivitelline fluid, which assists in making the attachment more permanent. The chorion eventually becomes drawn out at the point of attachment, and the egg appears to be attached to the seta by a stalk (see fig. 80).

According to Williamson, the number of eggs attached to the abdomen may vary from half a million in a small mature female to three millions in a large crab.

### Development.

It is a surprising fact that the development of *Cancer pagurus* has never been satisfactorily investigated. The internal changes do not appear to have been followed in any Brachyurous embryos, and although the general characters of the larval developments in the Brachyura are well known, our knowledge of these stages in *Cancer pagurus* is extremely scanty.

The development may be divided into three stages—embryonic, larval and post-larval.

The embryonic development takes place while the embryo is attached to the pleopods of the female, and, therefore, extends over a period of about seven months. The internal development during this period has not been investigated, but it is very probable that the Brachyura do not differ from the Macrura in this respect. The early development has been thoroughly investigated in the Macrura.†

* Williamson. *23rd Report, Scotch Fishery Board.*

† See Herrick, F. H. "The Development of the American Lobster," *Johns Hopkins Univ. Circ.*, Vol. IX, 1890, No. 80.

Reichenbach, H. "Studien zur Entwicklungsgeschichte des Flusskrebses," *Ab. Senkenberg. Nat. Ges. Frankfurt*, Bd. XIV, 1886.

While working at the Biological Station, Heligoland, I was able to examine the early larval stages of Cancer. I was fortunate enough to obtain berried crabs on which the embryos were ready for hatching. The process of hatching lasted several hours, and during this time the crab assisted by moving its abdomen backwards and forwards. The last walking legs were also used for the purpose of detaching the larvae from the pleopods. Unfortunately, I was not successful in keeping the larvae alive longer than the first zoëa stage.

I give below a summary of the characters of the larval stages of the Brachyura in general. I have utilised the results of other investigators,* and have also added my own observations. The larval stages may be divided into Protozoëa, Zoëa (four kinds) and Megalopa.

**Protozoëa** (Pl. XIII, figs. 83, 84). Hatching takes place at this stage, which is of very short duration. There are no frontal or dorsal spines present. The lateral spines (*sp. l.*) are present one on each side of the cephalothoracic shield. The large paired eyes are present in the head. The abdomen is well defined, but only five somites and the telson can be distinguished. The sixth somite is at this stage fused with the telson. The telson is forked, and each branch bears strong spines (fig. 84). All the cephalic and the first two pairs of thoracic limbs are present. The antennule is blunt and consists of two segments, of which the distal is the larger. The antenna consists of a broad basal joint, from which is given off a short pointed process. The mandible is a small rounded outgrowth. The first and second pairs of maxillae are

* Williamson, H. C. "On the Larval and Early Stages and Rate of Growth of the Shore Crab (*Carcinus maenas*)," *Twenty-first Annual Report, Fishery Board for Scotland*, p. 136.

Korschelt and Heider. *Text Book of Embryology* (Invertebrates, Part II).

similar, and are beginning to show evidences of a biramose structure. The first and second pairs of maxillipedes are large and biramose. The protopodite is large. The endopodite and exopodite have few setae. Towards the end of the protozoëa stage the cuticular covering becomes very loose, and beneath can be seen the developing organs of the first zoëa stage. Chromatophores are present at the sides of the body.

**First zoëa** (Pl. XIII, figs. 85, 86, 87). This stage is generally seen about three or four hours after hatching, and probably lasts for at least ten days. The important difference between this and the previous stage is the presence of the large frontal and dorsal spines. The latter is about half as long as the body, and the frontal spine is about two-thirds the length of the body. Both are tipped with a red pigment. The lateral spines are well developed. The branched chromatophores are well developed. The number of appendages appears to be the same as in the previous stage, but they are more highly developed. Each antennule bears a group of setae at its tip. The antennae and both pairs of maxillae are biramose. The exopodites of the maxillipedes each bear four long setae. The third maxillipedes and the pereiopods and the associated gills are present as extremely small buds, which are hidden beneath the cephalothoracic shield. The pleopods may be seen for the first time as extremely small tubercles. In some examples of both the protozoëa and the first zoëa there was a pair of tubercles present on the second abdominal somite. The telson differs from that of the previous stage in having two extremely long posterior branches.

**Zoëa stages II, III and IV.** I have not been able to identify these stages in *Cancer pagurus*, but in *Carcinus maenas* they have the following essential characters. They

are very similar to the first zoëa in appearance. Between the two branches of the antenna an outgrowth takes place in the second stages, and ultimately developes into the long flagellum. The maxillae are not very different from those of the first stage. The setae on the exopodites of the first and second maxillipedes increase in number at every stage. The last six pairs of thoracic appendages and their gills gradually increase in size, but never become functional during the zoëa stages. The pleopods gradually develop until at the fourth stage there are five pairs present. There is not a pair present on the sixth abdominal somite in Carcinus. At the third stage the sixth abdominal somite becomes separate from the telson. The rostral and dorsal spines gradually become shorter.

In his account of the larval stages of *Cancer irroratus*, Smith* describes the following characters in the last zoëa stage: Rostral and dorsal spines short. The abdominal legs are seen as stumpy outgrowths. The third maxillipede is well developed, but the other posterior thoracic appendages do not project below the edge of the cephalothoracic shield. The flagellum of the antenna is present.

**Megalopa stage.** The main points of difference between the zoëa and megalopa are as follows:—The frontal and lateral spines disappear. According to Smith, the dorsal spine of *Cancer irroratus* persists as a small backwardly-projecting process. The carapace is broader. The pereiopods are well developed, and the gills are probably functional. The pereiopods are never biramose as in the Macrura. The abdomen is macrurous, and the pleopods are used for swimming. The telson is much shorter, and loses its spines. The megalopa is still a pelagic stage. Its pereiopods, however, may be used for

* Smith, S. "The Invertebrate Fauna of Vineyard Sound," *U. S. Fish Commission Report*, 1871-72 (published 1873).

walking on the bottom. The last pereiopod in *Carcinus maenas* and *Cancer irroratus* has a tuft of setae on the dactylos. According to Smith, the megalopa stage is very short, and at the first moult it changes into a young adult.

**Post-larval stages.** The young adult differs from the megalopa in having the abdomen tucked beneath the thorax. It is no longer a pelagic animal, but lives on the bottom, and uses the last four pairs of pereiopods for the purposes of locomotion. As pointed out by Smith* and Cunningham,† the early post-larval stages differ considerably from the larger specimens. The carapace is elongated and the rostral region is well developed. The lobes of the antero-lateral border are sharp. Cunningham pointed out that it is difficult to distinguish the early stages of Cancer from those of *Atelecyclus heterodon*. At each succeeding moult the transverse axis of the carapace increases more rapidly than the longitudinal axis.

## ECONOMICS AND BIONOMICS.‡

The main features in the life-history of the edible crab may be briefly summarised as follows:—

*Cancer pagurus* is found all round the coasts of the British Isles, being especially abundant on the rocky coasts. The size at which maturity is attained is variable, but most crabs above five inches in breadth may be said to be mature. There appear to be no records of large

* Smith. *Op. cit.*

† Cunningham, J. T. "On the Early Post-larval Stages of the Common Crab (*Cancer pagurus*), and on the Affinity of that species with *Atelecyclus heterodon*," *Proc. Zool. Soc.*, 1898, Part II, p. 204.

‡ For further information on these subjects see—

Cunningham. *Cornwall County Council: Report of the Executive Committee for Fisheries*, 1897-8. Penzance, 1898.

Williamson. *Fishery Board for Scotland: 18th, 22nd, and 23rd Annual Reports.*

Wilson. *Northumberland Sea Fisheries Committee: Reports on*

edible crabs, but I have seen several specimens in shops having a carapace breadth of about twelve inches. A crab measuring nine inches would be considered a large one. The crabs are captured by means of crab-pots ("creels," Williamson; "creaves," Wilson), which are baited with fish. In Port Erin the chief fishing season is from March to September, but the crab fishery is continued throughout the winter. Generally speaking, the chief fishing season in the British Isles lasts from the early spring to the autumn. In some districts, such as the North-East of England, there is a close season.

Fishermen are not allowed to sell crabs below four and a half inches, berried crabs or soft crabs, but these restrictions do not hold good concerning crabs used for bait. Since, in some parts of the country, crabs are used for bait to a large extent, these laws for the protection of the crab fishery to some extent fail in their purpose. The size limit may be increased at the discretion of the local committees. In the Lancashire District the minimum size is five inches.

In the summer the mature crabs frequent the inshore waters, and in the winter they occur in the deeper off-shore waters. The immature crabs do not take part in this annual migratory cycle. The mature crabs cast in the autumn, and the females are fertilised when "soft." Spawning takes place in the deeper water in winter. The larvae are hatched in the following summer in the inshore waters. Wilson is of the opinion that the "berried"

*the Crab Fishery*, 1893 *and* 1895. Also *Proc. R. Soc. Edin.*, Vol. XX, 1894, p. 309.

Meek. *Northumberland Sea Fisheries Committee*, 1897-1906.

Buckland, Walpole and Young. *Reports on the Crab and Lobster Fisheries of England and Wales, of Scotland, and of Ireland* [C. 1695], 1877, p. 56.

Statistics regarding the crab fishery may be obtained from the various Annual Reports of Inspectors, Sea Fisheries (England and Wales).

crabs feed very little, and he records instances of such crabs being covered with sand. Williamson's observations appear to support this statement.

Baudouin* gives an interesting account of how the phenomenon of autotomy is utilised by the fishermen of Southern Spain. The common edible crab of that region is *Gelasimus tangeri*. When the crabs are captured the large claws are removed up to the fracture plane, and the crab is put back in the water. Only the claws are sent to market, the crab being returned to the sea to grow new ones.

The statistics published annually by the Fishery Inspectors for England and Wales are very scanty, and appear to have but little value in the elucidation of the numerous problems connected with the natural history of the edible crab.

I give below a summary of the figures published in the Annual Reports of the Fishery Inspectors for England and Wales since 1887, merely giving the total number of crabs caught in each year and their approximate value.

| Year. | Total Number. | Approximate Value. |
|---|---|---|
| 1887-1897 (average) | 4,669,861 | £55,082 |
| 1898 ..... | 5,628,114 | £67,895 |
| 1899 ..... | 4,918,184 | £62,494 |
| 1900 ..... | 5,177,350 | £56,822 |
| 1901 ..... | 5,325,974 | £58,743 |
| 1902 ..... | — | — |
| 1903 ..... | 4,923,536 | £54,327 |
| 1904 ..... | 4,580,318 | £52,556 |
| 1905 ..... | 5,106,345 | £59,479 |
| 1906 ..... | — | — |

* Baudouin, M. "Utilisation de l'autotomie chez un Crabe." *Revue scientifique* (Ser. V), T. VI, No. 10.

Through the kindness of Dr. Jenkins, Superintendent of the Lancashire and Western Sea Fisheries District, I am able to give the following statistics dealing with crabs landed in that Sea Fisheries District during the years 1900 to 1906, inclusive:—

| Year | New Quay. | | Aberdovey. | | Pwllheli. | | Holyhead. | | Liverpool. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | £'s. | No. | £'s. | No. | £'s. | No. | £'s. | No. | £'s. |
| 1900 | — | — | — | — | 6,000 | 180 | 600 | 6 | — | — |
| 1901 | — | — | — | — | 2,000 | 60 | 800 | 8 | — | — |
| 1902 | — | — | — | — | 10,204 | 112 | 1,100 | 11 | — | — |
| 1903 | — | — | — | — | 11,143 | 135 | 1,000 | 11 | 600 | 5 |
| 1904 | 50 | 1 | — | — | 10,710 | 125 | 615 | 6 | 900 | 8 |
| 1905 | 40 | 2 | — | — | 8,851 | 109 | 760 | 8 | 466 | 6 |
| 1906 | 509 | 11 | 435 | 7 | 9,347 | 113 | — | — | 800 | 8 |

The crabs returned as having been landed at Liverpool were certainly not caught in that District.

The Harbour Master of Port Erin has kindly provided me with the following figures, which give the number of crabs captured by the Port Erin fishermen during the years 1904-5-6:—

| | 1904. | 1905. | 1906. |
|---|---|---|---|
| January ..... | ? | 800 | 1,200 |
| February ..... | ? | 3,400 | 2,200 |
| March ..... | 7,000 | 6,500 | 4,000 |
| April ..... | 7,500 | 8,000 | 6,500 |
| May ..... | 7,500 | 9,400 | 7,000 |
| June ..... | 6,100 | 5,000 | 4,000 |
| July ..... | 7,000 | 6,500 | 7,000 |
| August ..... | 6,000 | 2,000 | 5,500 |
| September ..... | 3,000 | 2,000 | 2,500 |
| October ..... | 1,600 | 1,500 | 2,500 |
| November ..... | 500 | 400 | 300 |
| December ..... | 1,200 | 800 | 300 |
| Total ..... | 47,400* | 46,300 | 43,000 |

* The figures for January and February are not given.

## Fishery regulations.*

In section 8 of the Fisheries (Oysters, Crabs and Lobsters) Act (40 & 41 Vict. ch. 42), the following restrictions are imposed:—

A person shall not take or sell:—

(1) Any edible crab which measures less than four inches and a quarter across the broadest part of the back.

(2) Any edible crab carrying spawn.

(3) Any edible crab which has recently cast.

Such crabs may, however, be used for bait.

In the Lancashire and Western Sea Fisheries District the minimum legal size has been raised to five inches. (Bye-law 25*b*: "No person shall remove from a fishery any edible crab measuring less than five inches across the broadest part of the back.")

## Size of crabs at maturity.

*Female.*—There appears to be some difference of opinion with regard to the size at which the female becomes mature. Wilson† had reason to believe that on the Northumberland Coast the size of maturity is about six inches. Williamson's‡ investigations, on the other hand, show that the crabs of the east coast of Scotland become mature when about four and a half inches in width. I have examined crabs from Port Erin which had been fertilised when about this size. It is probable that a crab is mature when it has attained a size of four and a half inches, but in many cases fertilisation may not be effected until after the next casting. There is no

* For a discussion on this subject read Williamson, 18*th Annual Report*, p. 134. Other literature on this point is given by him on p. 78 of the same report.

† Wilson. *Northumberland and Sea-Fisheries Committee*, 1893, 1895; *Proceedings Royal Society, Edinburgh*, 1892-3, p. 309.

‡ Williamson. *Eighteenth Report*, p. 77.

doubt that many crabs do not bear their first batch of eggs until attaining a size of six inches.

*Male.*—The male crabs evidently attain maturity at a smaller size than is the case in the females. Probably all males above four and a half inches are mature, and Williamson has found mature males below this size.

Fertilisation takes place in the inshore waters during the late summer and autumn, and is effected immediately after the female has cast. The one supply of spermatozoa is probably sufficient for two successive batches of eggs, and even three in the older crabs. The spermatozoa remain in the spermathecae, and the entrances to the latter are closed by plugs, which are probably formed by a secretion from the walls of the spermathecae which hardens in contact with water.

The spawning of the eggs is effected in the deeper offshore waters during the winter. The eggs are attached to the endopoditic setae of the pleopods, and remain there until the following summer, when they are hatched in the inshore waters.

The crab probably does not cast after the larvae are hatched, but a second batch of eggs are spawned in the following winter in the offshore waters. As with the first batch, the developing embryos will be retained on the abdominal appendages until the following summer, when the hatching process will again take place in the inshore waters. After the second hatching the female probably casts, and is fertilised.

The developing embryos probably remain attached to the pleopods for about seven months. The various zoëa stages and the megalopa stage may extend over a period of two months, but our knowledge of the larval stages of Cancer is remarkably scanty. It is probable that the larvae hatched at the end of June will be in the first adult stage about the end of August.

## Distribution and Migration.

According to Williamson,* the crabs after the larval stages may be placed in four different groups according to their distribution.

*Group I* includes the young stages up to $\frac{1}{8}$-inch in breadth. These are probably restricted to the shallow shore waters.

*Group II* includes the crabs found on the beach between tide-marks. From $\frac{1}{8}$-inch to $2\frac{1}{4}$ inches in breadth.

*Group III* includes the crabs living in the littoral waters beyond low-water mark. From $2\frac{1}{4}$ to 4 inches.

*Group IV* includes all the crabs above 4 inches in breadth. These crabs are mostly mature, and migrate from the inshore waters in the summer to the deeper offshore waters in the winter.

With regard to Group I, my own observations confirm those of Williamson. In the spring and summer, when small specimens of Cancer must be very abundant, they are very rarely found between tide-marks. On the other hand, they are frequently taken in the dredge close to the shore.

The migration of the mature crabs has been long known to fishermen, and our knowledge with regard to this subject is now fairly complete, thanks to the work of Williamson, Meek and others. Only the crabs of Group IV are concerned in the migration, which may be divided into an offshore migration in the autumn and an inshore migration in the spring. Both hard and soft crabs begin to move outward into the deeper water in September (see Text fig. 13). The extreme depth to which they travel must necessarily vary with the locality, but it is generally between twenty and thirty fathoms.

* Williamson. *Eighteenth Annual Report.*

The crabs probably stay in the offshore waters from December to February, and it is here that the females spawn. The inshore migration begins in February, and in May the bulk of the crabs are probably back in the inshore waters again. The hatching of the larvae takes place in the warm inshore waters, and casting process is performed, and, in the case of the females, fertilisation is effected immediately after ecdysis. In the autumn the offshore migration again commences, and the cycle is repeated.

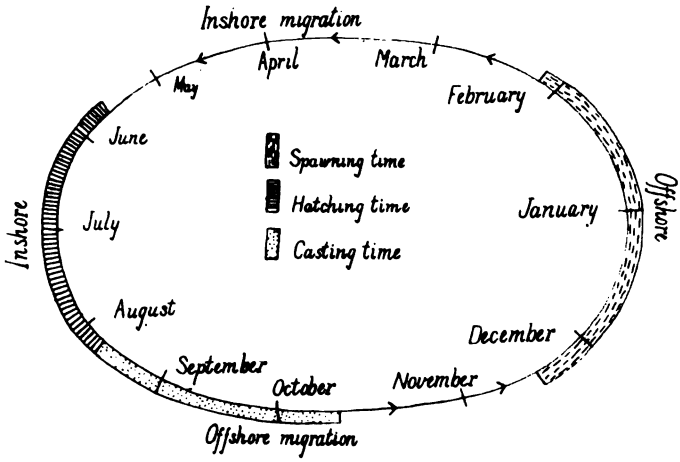



FIG. 13.—Diagram illustrating the annual migratory cycle of mature crabs. The three processes—casting, spawning and hatching—probably do not take place in one cycle.

It must be remembered, however, that in the mature female crab casting and fertilisation in the autumn is not necessarily followed by spawning in the same winter. Furthermore, casting will only take place once in two or three years. But when spawning does take place it is in the offshore waters, and the hatching is always in the inshore waters.

As suggested by Williamson, the main reason for

this regular migration is the influence of temperature. In the winter the deeper layers of the offshore waters are warmer than the inshore waters, and hence the former are most suitable for the spawning time. In the summer the shallower inshore waters become much warmer, and here the young larvae are hatched. It is also reasonable to suppose that the warm water of the inshore regions is specially favourable for the somewhat critical period of casting. The necessity for food may also have an important bearing on the yearly migration.

I give below a summary of the life-history of an adult female crab between two successive processes of ecdysis. The condition of the gonads at the various stages is discussed. In the example given, it is assumed that the crab did not spawn in the winter following fertilisation. The period elapsing between fertilisation and the first spawning appears to depend altogether on the condition of the gonads. As a rule, the ovary is very small and pale when ecdysis takes place, and in such a circumstance the eggs cannot possibly be ready for spawning in the course of three or four months. Consequently the eggs are not shed until the second winter, i.e. fourteen months after fertilisation. In some crabs the ovary is fairly ripe when ecdysis takes place, and in such cases the eggs will probably be extruded in a few months.

**First Year. September**—*The crab casts and is fertilised.*

It then migrates to offshore waters for the winter. It returns to inshore waters in the spring of the second year. In the following autumn offshore migration again takes place.

Condition of ovary. At first it is poorly developed and pale in colour, and the eggs are without food-yolk. The ovary gradually ripens, first becoming

pink in colour and finally a bright orange. This change in colour is due to the development of food-yolk. The eggs first become yolked in the spring of the second year.

**Second Year. December**—*Eggs extruded (first spawning).*

When the spawning takes place the crabs are in the deeper offshore waters. In the spring of the third year the inshore migration commences.

Condition of ovary. Immediately before spawning the eggs are large and of a bright orange colour, due to the food-yolk. After the extrusion of the eggs the ovary is shrunken and of a pale colour. The majority of the eggs are small and without food-yolk. There may be, however, a few ripe eggs present which have failed to escape to the exterior. As the spring advances the eggs gradually become more mature, and present a pinkish colour.

**Third Year. July**—*First hatching takes place.*

In the autumn of the third year the offshore migration again takes place.

Condition of ovary. At the time of the first hatching the ovary is generally of a red colour, and the eggs are about half ripe.

**Third Year. December**—*Eggs extruded (second spawning).**

During spawning time the crab is in the offshore waters. In the spring of the fourth year the inshore migration commences.

Condition of ovary. Very similar to the appearance at the time of the first extrusion.

**Fourth Year. July**—*Second hatching takes place.*

The crab is now in the inshore waters.

* Williamson gives instances in which the second spawning did not take place for about fifteen months after the first hatching. It is difficult to say whether this is of regular occurrence.

Condition of ovary. During the spring and summer the ovary remains unusually small, and has a pale colour. The eggs are mostly small and without yolk.

**Fourth Year. September**—*The crab casts and is fertilised.*

During these processes the crab is in the inshore waters. Immediately after fertilisation the offshore migration will commence, and the whole of the above history will be repeated.

Condition of ovary. Similar to that at the first casting.

### Bionomics of Ecdysis.

As already seen, the growth of the crab can only take place by the exuviation of hard shell or exoskeleton. Immediately after ecdysis has taken place the body—now covered by a soft flexible membrane—increases considerably in size. In the mature female fertilisation is also effected while the crab is soft. The soft crabs are not fit for food, and it is illegal to expose them for sale when in this condition.

### Season of casting.

The young crabs cast at various times of the year, but after the third year ecdysis generally takes place in the autumn. According to Williamson, the main casting period on the East Coast of Scotland is from July to September, but it may be extended to December. From August to November appears to be the chief casting time in the Isle of Man. The casting is effected in the warmer inshore waters. The hardening process in the mature crab lasts from three to five months, according to Williamson.

## Rate of Growth.

From the evidence obtained by Williamson and Waddington, and also from observations taken in the course of the present work, it would appear that the rate of growth varies considerably. For example, in a series of seventeen crabs measured in Heligoland I found that the fraction of increase varied from $\frac{1}{2 \cdot 5}$ to $\frac{1}{5 \cdot 8}$ (see table on p. 382). In Waddington's series published by Williamson* the fraction varied from $\frac{1}{2}$ to $\frac{1}{6 \cdot 5}$, and in the table published by Williamson† the ratio of increase varies from $\frac{1}{3 \cdot 1}$ to $\frac{1}{0}$. But, speaking generally, it may be said that this ratio is between $\frac{1}{3}$ and $\frac{1}{4}$.

It is not surprising that this rate of growth should be a variable one. The main factors to be considered are probably the general health of the animal (i.e. the condition of the tissues) the amount of food, the purity of the water and the temperature of the water, and many other causes. Any one of these factors would alone be capable of affecting very considerably the rate of growth.

I give a table (p. 382) showing the rate of increase in seventeen different crabs. These measurements were taken from specimens in the Nordsee Museum, Heligoland, by kind permission of the Director, Professor Heincke.

## Frequency of casting.

Speaking generally, it may be said that in the younger stages the moultings are frequent, but that as the crab grows older the period between each process of ecdysis and the next becomes longer.

In the earliest stages the frequency of casting differs in

* Williamson. *Twenty-second Annual Report, Fishery Board for Scotland*, p. 135.

† Williamson. *Eighteenth Annual Report, Fishery Board for Scotland*, p. 110 (see also Twenty-second Report, p. 122).

a marked degree in individuals of the same approximate age. As stated above, the hatching period lasts from

| | Carapace breadth before casting. Cm. | Carapace breadth after casting. Cm. | Ratio of Increase. |
|---|---|---|---|
| 1 | 1·55 | 2·05 | $\frac{1}{3·1}$ |
| 2 | 2·15 | 2·80 | $\frac{1}{3·3}$ |
| 3 | 2·25 | 2·95 | $\frac{1}{3·2}$ |
| 4 | 3·10 | 4·12 | $\frac{1}{3·0}$ |
| 5 | 3·12 | 3·82 | $\frac{1}{4·4}$ |
| 6 | 3·40 | 4·58 | $\frac{1}{2·8}$ |
| 7 | 4·00 | 5·25 | $\frac{1}{3·2}$ |
| 8 | 4·25 | 5·50 | $\frac{1}{3·4}$ |
| 9 | 4·45 | 5·55 | $\frac{1}{4·0}$ |
| 10 | 4·56 | 5·70 | $\frac{1}{4·0}$ |
| 11 | 5·20 | 6·60 | $\frac{1}{3·7}$ |
| 12 | 5·55 | 6·50 | $\frac{1}{3·8}$ |
| 13 | 5·55 | 7·20 | $\frac{1}{3·3}$ |
| 14 | 5·70 | 7·20 | $\frac{1}{3·8}$ |
| 15 | 6·50 | 9·10 | $\frac{1}{2·5}$ |
| 16 | 7·80 | 9·75 | $\frac{1}{4·0}$ |
| 17 | 12·80 | 15·50 | $\frac{1}{4·7}$ |

June to August. The "early" larvae, therefore, will have a considerable advantage over the "late" larvae.

Consequently, the early crabs will probably cast eight or nine times before the following summer, while the late crabs may have cast only five times. There will, also, be a corresponding difference in size.

It will be realised, therefore, that it is quite impossible to state the age of a crab with any degree of certainty. The size of the crab not only depends upon the frequency of casting, but also upon the ratio of increase at each act of ecdysis. As we have already seen, both these factors are subject to a considerable amount of variation. The most valuable information on this point is to be obtained from continued observations of crabs kept in an aquarium. This has been done to a certain extent by Mr. Waddington, of Bournemouth. But, even in such cases, we are not justified in establishing any broad principles on the results obtained. In the first place, there is no doubt that captivity affects the frequency of casting. There is also the same difficulty that obtains amongst crabs living amongst natural conditions, viz., that ratio and frequency of casting vary in individual crabs. This is demonstrated quite clearly by an examination of Waddington's* three series, in which both factors vary considerably.

But in spite of the impossibility of forming any definite laws with regard to the frequency of casting, a careful examination of all the available facts and figures enables one to give a general outline of the life-history of Cancer with regard to this particular point.

I propose, therefore, to give such an outline, but, in doing so, I must emphasise what I have already said—that we are dealing with factors which are by no means constant.

I intend taking a purely hypothetical case, utilising,

* Williamson. *Twenty-second Annual Report*, p. 135.

however, the stages of Waddington's Series A for the first two years.

**First year.** The larva was probably hatched in June. During the first year the crab cast eight times, and at the end of the first year (June to June) it was 30·75 mm. broad.

**Second Year.** The crab cast twice (September and March), and was 45·75 mm. broad at the end of its second year. (In the first two years the ratio of increase varied considerably. It will also continue to vary throughout life, but for practical purposes I intend taking the ratio of increase to be uniformly $\frac{1}{4}$, which is an average ratio.)

**Third year.** There will probably be two castings, so that at the end of the year the crab will be 70·6 mm. broad.

**Fourth year.** There will be only one ecdysis. At the end of the year the crab will be 88 mm. broad.

**Fifth year.** Only one casting. Size at the end of the year, 110 mm. The crab will now be mature, and if a female will probably be fertilised while in the "soft" condition.

**Sixth year.** The crab will not cast.*

**Seventh year.** The crab will cast once, and will be 137·5 mm. in width after ecdysis. Fertilisation will again be effected when the crab is "soft."

**Eighth year.** The crab will not cast.

**Ninth year.** The crab will cast, and after ecdysis will be 171·8 mm. broad. Fertilisation will take place immediately after ecdysis.

I believe it to be highly probable that after the female crab attains a size of six inches (150 mm.) ecdysis will only take place once in three years (see below under

* There is every reason to believe that after attaining maturity the crabs only cast once in two years.

"Granny" Crabs). If a male, it will probably cast once in two years.

| | First Year. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Number of Casting ... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Width in mm. ..... | 4·75 | 5·75 | 8·5 | 10·75 | 14·5 | 19·5 | 24·5 | 30·75 |
| Width in inches ..... | ($\frac{1}{5}$) | ($\frac{1}{4}$) | ($\frac{1}{3}$) | ($\frac{2}{5}$) | ($\frac{3}{5}$) | ($\frac{4}{5}$) | (1) | ($1\frac{1}{4}$) |

| | Second Year. | | Third Year. | |
|---|---|---|---|---|
| Number of Casting ..... | 9 | 10 | 11 | 12 |
| Width in mm. ..... | 36·5 | 45·75 | 56·5 | 70·6 |
| Width in inches ..... | ($1\frac{1}{2}$) | ($1\frac{3}{4}$) | ($2\frac{1}{4}$) | ($2\frac{3}{4}$) |

| | Fourth Year. | Fifth Year. | Sixth Year. |
|---|---|---|---|
| Number of Casting | 13 | 14 | Did not cast |
| Width in mm. ..... | 88·2 | 110·0 | — |
| Width in inches ..... | ($3\frac{1}{2}$) | ($4\frac{1}{2}$) | — |

| | Seventh Year. | Eighth Year. | Ninth Year. |
|---|---|---|---|
| Number of Casting | 15 | Did not cast | 16 |
| Width in mm. ..... | 137·5 | — | 171·8 |
| Width in inchcs ..... | ($5\frac{1}{2}$) | — | ($6\frac{3}{4}$) |

| | Tenth Year. | Eleventh Year. | Twelfth Year. |
|---|---|---|---|
| Number of Casting | Did not cast | Did not cast | 17 |
| Width in mm. ... | — | — | 214·7 |
| Width in inches ... | — | — | ($8\frac{1}{2}$) |

The approximate calculations given above do not lend support to Williamson's statement that "a crab of four and a quarter inches across would be not less than three years, nor probably more than four years old." Even if we take a growth ratio of one-third, which is rather high, we find that the crab would not reach the

size of four and a quarter inches until the fourth year at the earliest.

There is abundant evidence to show that the adult male and female crabs do not cast every year, but probably only once in two years. There appears to be little doubt, moreover, that in the older crabs ecdysis may take place less frequently than once in two years, and Williamson has given several instances of crabs in which the shell is undoubtedly more than two years old. In the Nordsee Museum, Heligoland, there is a female Cancer, with a carapace breadth of 17 cm., having attached to the shell, an Anomia 5·8 cm. in width.

Although there appears to be a stage in the life-history of Cancer after which ecdysis is only triennial, no attempt has been made to determine at which period the change from a biennial to a triennial growth takes place.

Such an investigation presents innumerable difficulties, and the only way in which the problem can be satisfactorily solved is either by having large crabs under observation in captivity for many years, or by the careful analysis of a great number of exact measurements made for the purpose. Neither of these methods has been followed, and although Williamson has been able to gather a mass of extremely useful information, his statistics do not appear to be of much value in the elucidation of this particular problem.

Our present knowledge with regard to the frequency of casting may be briefly summarised as follows. In the early stages the young crab casts frequently. As it grows older the periods between successive castings become longer, and it is probable that after reaching maturity both males and females cast only once in two years. There is scattered evidence to show that many large crabs

cast less frequently than once in two years, and a stage is ultimately reached when the crab ceases to cast.

It is my belief that after attaining a size of about six inches carapace breadth the females, as a general rule, only cast once in three years, but that the males continue to cast biennially for a considerably longer period. It must be admitted that the figures on which this suggestion is based are not sufficiently large to warrant any conclusive statements on the subject. So that, although I feel that my explanation is a reasonable one, and is, furthermore, supported by many facts, I bring it forward merely as a provisional hypothesis. I further recognise that, just as in the case of the younger stages, there can be no rigid law regarding the frequency of casting. It is quite possible that many males over six inches cast less frequently than once in two years, and that many females above this size may cast biennially.*

### *"Granny" Crabs.*

The assumption that female crabs above six inches cast only once in three years was first suggested to me when examining into the nature of "granny" crabs. This name is given by the fishermen of Port Erin to crabs occurring in the late summer and early autumn which have dirty and discoloured shells and broken claws. These crabs, if eaten, have a bitter taste and a powerful purgative effect. The fishermen believe they are diseased crabs, and always kill such when captured. There appears to be no adequate reason for believing that these crabs are diseased. The fact that they occur in considerable numbers every year during the late summer and early autumn is sufficient to render this suggestion doubtful. The general condition of these crabs leads me

* Williamson has pointed out that if the soft mature female fails to be fertilised, it will probably cast again in the following year.

to believe that they are merely crabs ready for casting.*

Mr. T. N. Cregeen, of the Biological Station, Port Erin, kindly examined and measured for me a number of crabs during the summer of 1907. The table inserted below gives a summary of the results obtained.

One thousand and ninety-four crabs were examined, and of this number 318 were males and the remainder females. Of the 776 females, 112 were "grannies." It will be observed that there are no male "grannies" in the list, and that practically the whole of the female "grannies" are six inches or more in width. General information from Port Erin bears this out. Male "grannies" and small female "grannies" are almost unknown.

Crabs obtained between the Calf of Man and Bradda Head, Port Erin, during the summer (July to September) of 1907.

| Greatest breadth of Carapace (in inches). | Males. | Females. | | Total. |
|---|---|---|---|---|
| | | Normal. | "Granny." | |
| 3½—4 | — | 2 | — | 2 |
| 4—4½ | 27 | 16 | — | 43 |
| 4½—5 | 63 | 31 | — | 94 |
| 5 —5½ | 67 | 90 | — | 157 |
| 5½—6 | 54 | 153 | 3 | 210 |
| 6 —6½ | 38 | 164 | 18 | 220 |
| 6½—7 | 23 | 100 | 36 | 159 |
| 7 —7½ | 16 | 58 | 31 | 105 |
| 7½—8 | 15 | 30 | 19 | 64 |
| 8 —8½ | 13 | 14 | 4 | 31 |
| 8½—9 | 1 | 6 | 1 | 8 |
| 9 —9½ | 1 | — | — | 1 |
| Totals..... | 318 | 664 | 112 | 1,094 |

* In "granny" crabs that I have examined there has been a well-defined cuticle beneath the hard exoskeleton. This condition is found in crabs preparing for ecdysis.

As already stated, mature crabs generally cast from August to November, and immediately before and after ecdysis their flesh is "watery" and has a bitter taste, and is, therefore, unfit for food. The above symptoms are also characteristic of the "granny" crab.

"Grannies" are found only amongst females above six inches in breadth. The explanation of this is that those females below this size do not retain their shells long enough for the latter to acquire the discoloured and broken appearance. An interval of two years between successive castings is evidently insufficient to produce this effect.

This diminution in the frequency of casting in the females above six inches may be due to the general rule that as the crab grows older the period between successive castings tends to become longer until a time is reached when ecdysis ceases altogether. But this explanation does not appear to be sufficient to account for the supposed difference between males and females in this respect. An important factor in determining the time of casting is the condition of the reproductive organs. Ecdysis will not take place in the female so long as there is a supply of spermatozoa in the spermathecae. The supply of spermatozoa received by the soft female is generally sufficient to fertilise at least two batches of eggs in successive winters, and it is highly probable that the older crabs will spawn three times between each moult. Williamson has emphasised this point, and has also stated that the soft female which, for any reason, does not become fertilised, will cast in the following summer. The frequency of ecdysis, then, in mature females is influenced by the condition of the spermathecae, and it is probable that on this account the older females will cast less frequently than the younger ones.

These conditions do not affect the male. In the female the casting time is of double importance, as it is at that period that fertilisation is effected. In the male, however, ecdysis would appear to be important only as a period of growth. It appears to me, therefore, from an examination of all the evidence obtainable, that male crabs above six inches in breadth continue to cast once in two years, and it is probable that this is the case until ecdysis stops. This rule cannot be an invariable one, as there are a few records of male crabs which have not undergone the casting process for at least three years.

My suggestion that the males above six inches cast more frequently than the females of a similar size, and, therefore, do not become "grannies," is borne out, not only by an examination of the statistics given above, but also by some figures which I quote from Williamson.* These figures give a comparison of hard and soft mature crabs taken off Dunbar. I have only included those figures dealing with the casting period.

| Date. | Hard crabs above 4½ins. | | Soft crabs above 4½ins. | |
|---|---|---|---|---|
| | Males. | Females. | Males. | Females. |
| Aug. 4, 1899 ..... | 26 | 77 | 1 | 8 |
| Sept. 23, 1899 ..... | 76 | 104 | 235 | 144 |
| Oct. 27, 1899 ..... | 83 | 160 | 140 | 87 |
| Nov. 5, 1898 ..... | 269 | 206 | 64 | 32 |
| Nov. 17, 1899 ..... | 117 | 60 | 66 | 48 |
| Dec. 13, 1899 ..... | 196 | 200 | 56 | 42 |
| Dec. 20, 1897 ..... | 60 | 110 | 22 | 4 |
| Totals..... | 827 | 917 | 584 | 365 |

Total number of males ..... 1,411
„ „ females ..... 1,282

In other words, for every 100 males (hard and soft) there are 91 females (hard and soft). For every 100 soft

* Williamson. *Eighteenth Report*, page 102, Table V.

males there are only 62 soft females. This points to the fact that the mature males cast more often than the females. It is probable that both males and females of between four and a quarter inches and six inches cast once in two years, so that it is in the older crabs that the males cast more frequently than the females. I do not attach too much importance to the above figures, as the numbers are too small to justify their use in the question of the frequency of casting. So far as they go, however, they confirm my statement that the female crabs over six inches do not cast so often as the males of a similar size. It is, therefore, probable that the "granny" crabs are not diseased, but are merely females ready for casting. They are only found amongst females of over six inches in breadth. The reason why smaller females and males of all sizes do not become "grannies" is because they cast at least once in two years.

I have been unable to find any reference to "granny" crabs in the literature* of the subject, but Williamson says "as a rule the shell of the old female crab is much more dirty than that of the male."† He attributes this dirtiness to the fact that the female when carrying eggs lies half buried in the mud. This explanation may have some truth in it, but it does not solve the problem as to why only female crabs above six inches in breadth become discoloured.

It is evident that the various processes which are characteristic of the life-history of the edible crab are subject to considerable variation, and it is necessary that further investigations should be made before the numerous problems can be regarded as being solved.

* With the exception of a preliminary notice by Professor Herdman in *Twenty-first Annual Report of the L.M.B.C. (Port Erin Marine Biological Station)*, p. 25.

† Williamson. *Eighteenth Report*, p. 110.

# EXPLANATION OF PLATES.

## Reference Letters.

*a. acc.*—Anterior accessory muscle of the scaphognathite.
*a. art.*—Antennary artery.
*ab.* 1—6.—Abdominal somites 1 to 6.
*abd.*—Abdomen.
*abs.*—Lines of absorption.
*a. ex. B.*—Tendon of the anterior extensor of basi-ischium of chela.
*af.*—Afferent branchial sinus.
*af.* 1.—Do. of the podobranch of the second thoracic somite.
*af.* 2.—Do. of the arthrobranch of the second thoracic somite.
*af.* 3.—Do. of the podobranch of the third thoracic somite.
*af.* 4.—Do. of the anterior arthrobranch of the third thoracic somite.
*af.* 5.—Do. of the posterior arthrobranch of the third thoracic somite.
*af.* 6.—Do. of the anterior arthrobranch of the fourth thoracic somite.
*af.* 7.—Do. of the posterior arthrobranch of the fourth thoracic somite.
*af.* 8.—Do. of the pleurobranch of the fifth thoracic somite.
*af.* 9.—Do. of the sixth thoracic somite.
*a. f. fl.*—Anterior flexor of the flabellum of the first maxillipede.
*a. gl.*—Antennary gland.
*a. i. p.*—Antero-inferior pyloric ossicle.
*a. lb.*—Antero-lateral lobe of the bladder.
*a. mes.*—Anterior mesopyloric ossicle.
*amp.*—Pyloric ampulla.
*amp. C.*—Supra-ampullary ridge.
$a^1$. *n.*—Nerve of the first antenna; $a^2$. *n.*—Nerve of the second antenna.
*ant.*—Second antenna; $ant^{1c}$.—First antenna (antennule).
*a. oe. lb.*—Anterior oesophageal lobe of the bladder.
*ao. lb.*—Outer portion of the antero-lateral lobe of the bladder.
*a. ost.*—Anterior ostia of the heart.
*a. pl.*—Anterior pleuropyloric ossicle.
*apoph.*—Apophysis of the mandible.
*art.* 1—*etc.*—Branches of the sternal artery supplying the first and following post-oral cephalothoracic appendages.
*a. s.*—Antero-superior dilator muscles of the fore-gut.
*a. s. a.*—Anterior supra-ampullary ossicle.
*as. lb.*—Anterior oesophageal lobe of the bladder.
*a. t. l.*—Lateral accessory tooth.

*B.*—Basipodite.
*bc.* 1—5.—Branchio-cardiac veins 1 to 5.
*B-I.*—Basi-ischiopodite.
*bl.*—Bladder.
*b. m.*—Basement membrane.
*br.*—Gills.
*br. ch.*—Branchial chamber.
*br. e.*—Branchial excretory organ.
*br. s.* 1—5.—Branchial sinuses 1 to 5.

*C.*—Coxopodite.
$C^1$.—Carpopodite.
*caec.*—Mid-gut caecum.
*c. al.*—Antero-lateral cardiac muscles.
*c. ant.*—Anterior cardiac muscles.
*card.*—Cardiac portion of the fore-gut.
*cd.* 1.—Dorsal antero-lateral muscles of the heart.
*cd.* 2.—Ventral antero-lateral muscles of the heart.

*cd.* 3.—Dorsal postero-lateral muscles of the heart.
*cd.* 4.—Ventral postero-lateral muscles of the heart.
*cd.* 5.—Posterior muscle of the heart.
*cd.* 6.—Lateral posterior muscle of the heart.
*cd. al.*—Antero-lateral cardiac plate.
*cd. pl.*—Postero-lateral cardiac plate.
*c. g.*—Cerebral ganglia.
*ch.*—Chela.
*ch. ep.*—Epidermis (chitogenous epithelium).
*c. i.*—Postero-inferior cardiac muscle.
*c. lat.*—Lateral cardiac muscles.
*c. m.*—Circular muscles.
*c. lob.*—Cerebral lobe of the bladder.
*cn.*—Cornea.
*c. oe.*—Constrictor muscles of the oesophagus.
*Com.*—Commissure.
*corn.*—Corneagen (cells of ommatidium).
*c. p. v.*—Cardio-pyloric valve.
*c. py.*—Cardio-pyloric muscles.
*c. t.*—Connective tissue.
*ct. gl.*—Cutaneous gland.
*cut.*—Cuticle.

*D.*—Dactylopodite.
*d. ai.*—Antero-inferior dilator muscle of the cardiac fore-gut.
*d. art.*—Descending artery.
*Der.*—Dermis.
*d. ex. C.*—Tendon of the dorsal extensor muscle of the coxopodite.
*d. f. ex.*—Dorsal flexor muscle of the exopodite.
*d. g.*—Duct of the gland.
*di. gl.*—Digestive gland.
*d. l.*—Deeper layer of the cornea.
*d. la.*—Antero-lateral dilator muscle of the cardiac fore-gut.
*d. lp.*—Postero-lateral dilator muscle of the cardiac fore-gut.
*d. sup.*—Dorsal pyloric muscle.
*d. v. m.*—Dorso-ventral muscles.

*E.*—Epistoma.
*e. a. md.*—External adductor muscle of the mandible.
*e. b. md.*—External abductor muscle of the mandible.
*e. bl.*—Epithelium of the bladder.
*e. d.*—Ejaculatory duct.
*e. es.*—Epithelium of the end-sac.
*ef.*—Efferent vessel.
*ef.* 1—9.—Efferent vessels of gills 1 to 9.
*e. lb.*—Epigastric lobe of the bladder.
*end.*—Endopodite.
*end. s.*—End sac.
*ep.* 4—12.—Endopleurites of somites 4 to 12.
*epm.* 1—19.—Epimera of somites 1—19.
*e. st.* 4—12.—Endosternites of somites 4 to 12.
*e. st.* 13.—Last thoracic arthrophragm ("sella turcica").
*e. tu.*—Epithelium of the renal tubule of the labyrinth.
*ex.*—Exopodite.
*ex.* 1—6.—Extensor muscles of the abdominal somites 1 to 6.
*ex. B.*—Tendon of the extensor muscle of the basi-ischiun.
*ex. C.*—Tendon of the extensor muscle of the coxopodite.
*ex. C*$^1$.—Tendon of the extensor muscle of the carpopodite.
*ex. fl.* (Fig. 29).—Extensor muscle of the flabellum.

*ex. fl.* (Fig. 30).—Extensor muscle of the flagellum.
*ex. prot.*—Extensor muscle of the protopodite.
*ex. py.*—Exopyloric ossicle.
*ext. D.*—Tendon of the extensor muscle of the dactylopodite.
*ext. ex.*—Extensor muscle of the exopodite.
*ext. P.*—Tendon of the extensor muscle of the propodite.
*ex. tel.*—Extensor muscle of the telson.

*f.* 1—6.—Flexor muscles of the abdominal somites 1 to 6.
*f. B.*—Tendon of the flexor muscle of the basi-ischium.
*f. c.*—Fat cell of the digestive gland.
*f. C.*—Tendon of the flexor muscle of the coxopodite.
*f. C'.*—Tendon of the flexor muscle of the carpopodite.
*f. D.*—Tendon of the flexor muscle of the dactylopodite.
*flab.*—Flabellum (epipodite).
*flag.*—Flagellum.
*fl. m.*—Muscles from the top of the "gland" to the carapace.
*f. m.* 1.—Flabellum of the first maxillipede.
*f. m.* 2.—Flabellum of the second maxillipede.
*f. m.* 3.—Flabellum of the third maxillipede.
*f. m. c.*—Ferment cell of the digestive gland.
*f. o.*—External female genital opening.
*f. p.*—Fracture plane.
*f. P.*—Tendon of the flexor muscle of the propodite.
*f. prot.*—Flexor muscle of the protopodite.
*f. tel.*—Flexor muscle of the telson.
*f. v.*—Ferment vesicle.

*g.* 1.—First gill. Podobranch of the second thoracic somite.
*g.* 2.—Second gill. Arthrobranch of the second thoracic somite.
*g.* 3.—Third gill. Podobranch of the third thoracic somite.
*g.* 4.—Fourth gill. Anterior arthrobranch of the third thoracic somite.
*g.* 5.—Fifth gill. Posterior arthrobranch of the third thoracic somite.
*g.* 6.—Sixth gill. Anterior arthrobranch of the fourth thoracic somite.
*g.* 7.—Seventh gill. Posterior arthrobranch of fourth thoracic somite.
*g.* 8.—Eighth gill. Pleurobranch of the fifth thoracic somite.
*g.* 9.—Ninth gill. Pleurobranch of the sixth thoracic somite.
*g. a.*—Anterior gastric muscle.
*g. f.*—Fat globules.
*g. lb.*—Paragastric lobe of the bladder.
*g. p. e.*—External posterior gastric muscle.
*g. p. i.*—Internal posterior gastric muscle.

*h.*—Seta of the endopodite of the pleopod of the female.
*h. art.*—Hepatic artery.
*h. g.*—Hind gut.
*h. l.*—Hepatic lobe of the bladder.

*I.*—Ischiopodite.
*ia. art.*—Inferior abdominal artery.
*i. a. f.*—Inter ampullary fold.
*i. a. md.*—Internal adductor muscle of the mandible.
*i. b. md.*—Internal abductor muscle of the mandible.
*i. b. s.*—Inter-branchial septum.
*i. caec.*—Hind-gut caecum.
*i. e. m.*—Inner flexor muscle of the first maxilla.
*i. ex.*—Inner flexor muscle of the scaphognathite (*i. ex. s.*, Figs. 27, 31).
*i. f.*—Inner extensor muscle of scaphognathite.
*i. f. m.*—Inner extensor muscle of first maxilla.

*i. gl.*—Glands of the hind-gut.
*i. l.*—Infero-lateral cardiac tooth.
*i. m. ex.*—Inner median flexor muscle of the scaphognathite.
*i. m. f.*—Inner median extensor muscle of the scaphognathite.
*i. py. e.*—External inferior dilator muscle of the pyloric fore-gut.
*i. py. i.*—Internal inferior dilator muscle of the pyloric fore-gut.
*i. s.*—Infra-branchial sinus.

*j. d.*—Junction between the descending artery and the sternal artery.

*l.*—Gill lamella.
*lab.*—Labrum.
*lat. t.*—Lateral teeth.
*l. ex. prot.*—Lateral extensor muscle of the protopodite.
*l. f. prot.*—Lateral flexor muscle of the protopodite.
*l. g. n.*—Lateral gastric nerve.
*lig.*—Ligament.
*l. m.*—Longitudinal muscle.
*l. py.*—Lateral pyloric ossicle.
*l. s.*—Lamella blood sinus.

*M.*—Meropodite.
*m.a*$^1$.—Muscle chamber of first antenna.
*m.a*$^2$.—Muscle chamber of second antenna.
*mand.*—Mandible.
*m. c.*—Mesocardiac ossicle.
*md. palp.*—Mandibular palp.
*med. p.*—Median plate of endophragmal system.
*met.*—Metastoma.
*m. ex. C'.*—Extensor muscle of the carpopodite.
*m. ex. M.*—Extensor muscle of the meropodite.
*m. ext. D.*—Extensor muscle of the dactylopodite.
*m. ext. P.*—Extensor muscle of the propodite.
*m. f. C'.*—Flexor muscle of the carpopodite.
*m. f. D.*—Flexor muscle of the dactylopodite.
*m. f. M.*—Flexor muscle of the meropodite.
*m. f. P.*—Flexor muscle of the propodite.
*m. g.*—Mid-gut.
*m. o.*—Male genital opening.
*m. py.*—Middle pyloric ossicle.
*m. s. a.*—Middle supra-ampullary ossicle.
*M. V.*—Main vesicle.
*mx*$^1$.—First maxillipede.
*mx*$^2$.—Second maxillipede.
*mx*$^3$.—Third maxillipede.

*n.*—Nucleus.
*n.* 1.—*n.* 9.—Nerves arising from the ventral nerve mass of the thorax.
*n. ab.*—Abdominal nerve.
*n. c.*—Nerve commissure.
*n. f.*—Foramen of ventral nerve mass for descending artery.
*n. i.*—Nerve to hind-gut.
*n. l.*—Nerve to digestive gland.
*n. m.*—Nerve to the mandibular muscles.
*n. po.*—Transverse post-oesophageal connective.
*n. t.*—Nerve to the integument.

*o.*—Eye.
*o. art.*—Ophthalmic artery.
*oe.*—Oesophagus.

*oe. ai.*—Antero-inferior dilator muscle of the oesophagus.
*oe. as.*—Antero-superior dilator muscle of the oesophagus.
*oe. l.*—Lateral dilator muscle of the oesophagus.
*o. e. m.*—Outer flexor muscle of the first maxilla.
*oe. p.*—Posterior dilator muscle of the oesophagus.
*o. ex.*—Outer flexor muscle of the scaphognathite (*o.ex.s.*, Figs. 27, 31).
*o. f.*—Outer extensor muscle of the scaphognathite.
*o. f. m.*—Outer extensor muscle of the first maxilla.
*o. g.*—Optic ganglion.
*o. l. s.*—Outer lamellar sinus.
*o. m. c.*—Ophthalmic muscle chamber.
*o. m. ex.*—Outer median flexor muscle of the scaphognathite.
*o. m. f.*—Outer median extensor muscle of the scaphognathite.
*om. n.*—Oculo-motor nerve.
*o. n.*—Optic nerve.
*o. n. fib.*—Optic nerve fibres.
*op.*—Operculum of excretory opening.
*op*[1].—Inner side of operculum.
*op. b. s.*—Ophthalmic blood sinus.
*o. ped.*—Optic peduncle.
*o. py.*—Pyloric ossicle.
*orb.*—Orbit.
*ov.*—Ovary.
*ov. art.*—Ovarian artery.
*ovd.*—Oviduct.

*P.*—Propodite.
*P.* 1—4.—Walking legs 1 to 4.
*p.* 1—2.—1st and 2nd abdominal appendages of male.
*p. acc.*—Posterior accessory muscle of the scaphognathite.
*p. c. p.*—Pro-cephalic processes.
*pec.*—Pectineal ossicle.
*ped.*—Eye peduncle.
*Per.*—Pericardium.
*per. gl.*—"Pericardial pouch."
*p. ex. B.*—Tendon of the posterior extensor muscle of the basi-ischium.
*p. f. B.*—Tendon of the posterior flexor muscle of the basi-ischium.
*p. g.*—Paroesophageal ganglion.
*pg. c.*—Pigment cell.
*pg. i.*—Inner pigmented layer of the eye.
*p. g. n.*—Posterior gastric nerve.
*pg. o.*—Outer pigmented layer of the eye.
*pig. l.*—Pigment layer.
*pl. art.*—Postero-lateral artery.
*p. lb.*—Progastric lobe of the bladder.
*p. mes.*—Posterior mesopyloric ossicle.
*p. n.*—Postero-lateral nerve.
*pod. br.*—Podobranch.
*p. o. lb.*—Post-oesophageal lobe of the bladder.
*p. ost.*—Posterior ostia of the heart.
*pp.*—Pleuropyloric wall.
*p. pec.*—Prepectineal ossicle.
*prot.*—Protopodite.
*pr. p.*—Propyloric ossicle.
*p. s. a.*—Posterior supra-ampullary ossicle.
*pt. c.*—Pterocardiac ossicle.
*pt. pec.*—Post-pectineal ossicle.
*pyl.*—Pyloric region of the fore-gut.
*py. lat.*—Lateral pyloric muscles.

*r. br.*—Roof of the pre-branchial chamber.
*ret.*—Cells of the retinula.
*rhab.*—Rhabdome.
*rost.*—Rostrum.

$S^1$. —$S^{19}$. —Sterna of somites 1 to 19.
*s.* $a^1$. —Socket of first antenna.
*s.* $a^2$. —Socket of second antenna.
*sa. art.*—Superior abdominal artery.
*s. amp.*—Supra-ampullary wall of the pyloric region of the fore-gut.
*sal. g.*—Salivary (œsophageal) glands.
*s. art.*—Sternal artery.
*sb.*—Striated border of the cell.
*scaph.*—Scaphognathite.
*s. ch.*—Blood sinus from the chela.
*s. dt.*—Subdentary ossicle.
*s. h., s. hr.*—Sub-hepatic region of carapace.
*s. l.*—Supraciliary lobe.
*s. lb.*—Supra-hepatic lobe of the bladder.
*s. mx.* 2.—Blood sinus from the second maxillipede.
*s. mx.* 3.—Blood sinus from the third maxillipede.

*s. Pi.*—*s. P.* 4.—Blood sinus from the walking legs 1 to 4.
*sp. a.*—Frontal spine.
*sp. d.*—Dorsal spine.
*sp. l.*—Lateral spine.
*spt.*—Spermatheca.
*st.*—Stalk of the egg attached to the seta of the endopodite.
*st. g.*—Stomatogastric ganglion.
*st. i.*—Inferior root of the stomatogastric nerve.
*st. n.*—Stomatogastric nerve.
*st. s.*—Superior root of the stomatogastric nerve.

*t. e. ex.*—Tendon of the extensor muscle of the exopodite.
*tel.*—Telson.
*test.*—Testis.
*t. ex. ab.*—Tendon of the external abductor muscle of the mandible.
*t. ex. ad.*—Tendon of the external adductor muscle of the mandible.
*t. ex. M.*—Tendon of the extensor muscle of the meropodite.
*t. f. ex.*—Tendon of the flexor muscle of the exopodite.
*t. g., t. gm.*—Ventral thoracic nerve mass.
*t. int. ad.*—Tendon of the internal adductor muscle of the mandible.
*t. n.*—Tegumentary nerve.
*tu.*—Renal tubule of the labyrinth.

*u. c.*—Urocardiac ossicle.
*up. f.*—Uropyloric fold.
*u. py.*—Uropyloric ossicle.

*v.*—Globules in the epithelial cells of the mid-gut.
*val.*—Pyloric valves.
*v. d.*—Vas deferens.
*v. ex. C.*—Tendon of the ventral extensor muscle of the coxopodite.
*v. f. ex.*—Ventral flexor muscle of the exopodite.
*vit.*—Vitrella (cells of the ommatidium).
*v. m.*—Egg membranes.
*v. oe. g.*—Ventral œsophageal cutaneous glands.

*y. c.*—Young cells of the tubules of the digestive gland.
*y. gr.*—Yolk granules.

*z. c.*—Zygocardiac ossicle.

## Plate I.

Fig. 1. *Cancer pagurus*, from above. Small specimen.
Fig. 2. *C. pagurus*, female, from below. Only the stumps of the pereiopods are shown. This figure shows the shape of the abdomen, and also the "pleural groove." × ½.
Fig. 3. *C. pagurus*, male, from below. Only the stumps of the pereiopods are shown. × ½.

## Plate II.

Fig. 4. First antenna (antennule) of right side, seen from below. × 2.
Fig. 5. Right second antenna, from below. × 2.
Fig. 6. Right mandible, from below. The apophysis is also shown with the tendons of the external adductor, the internal adductor and the external abductor muscles. × 1.
Fig. 7. Right first maxilla, from below. × 1.
Fig. 8. Right second maxilla and scaphognathite, from below. × 1.
Fig. 9. Right first maxillipede, from below. × 1.
Fig. 10. Right second maxillipede, with podobranch, from below. × 1.
Fig. 11. Right third maxillipede, with podobranch, from below. × 1.
Fig. 12. Anterior view of the right chela (first pereiopod). × 1.
Fig. 13. Anterior view of the right third walking leg (fourth pereiopod). × 1.
Fig. 14. First abdominal appendage of male of right side. × 1.
Fig. 15. Second abdominal appendage of male of right side. × 1.
Fig. 16. First and second abdominal appendage of male, viewed from left side. × 1.
Fig. 17. Anterior view of a right abdominal appendage of female. × 1.

## Plate III.

Fig. 18. The endophragmal system viewed from above. On the right side the thoracic epimera have been removed in order to display the endopleurites. The following parts have also been removed:—The carapace, with the exception of the anterior portion of the sub-hepatic region; the membranous roof of the branchial chamber; the abdomen; the cephalothoracic appendages (with the exception of the mandibles); the gills; and all the soft parts of the body. × 1.

Fig. 19. The sternum of the pre-oral cephalic region, viewed from above. The dorsal part of the carapace has been removed, as well as the pre-oral cephalic appendages and the soft parts. × 2.

Fig. 20. The sternum of the pre-oral cephalic region, from below. The first and second antennae of the left side have been removed to display their sockets and muscle chambers. The long peduncle of the left eye is shown, and also the labrum. × 2.

Fig. 21. Anterior and ventral view of the right chela. The anterior wall of each segment has been cut out, and the soft parts removed in order to display the tendons. × $\frac{2}{3}$.

Fig. 22. Posterior view of the basal portion of the second walking leg (right side). The posterior wall of the coxopodite has been removed in order to display the tendons of that segment and also of the basi-ischium. × 1.

Fig. 23. Posterior view of the base of the last walking leg of the right side. The posterior wall of the coxopodite has been removed in order to display the tendons of the coxopodite and of the basi-ischium. × 1.

## Plate IV.

Fig. 24. Vertical section through the integument of a soft crab. × 550.

Fig. 25. Right abdominal appendage of female, viewed from behind. To show the muscles of the protopodite and exopodite, the posterior walls of the protopodite, exopodite and endopodite have been removed. × 3.

Fig. 26. Anterior view of the right first maxilla, in order to show the muscles. × 2.

Fig. 27. Anterior view of the right second maxilla, to show the extensor muscles of the scaphognathite. × 1½.

Fig. 28. Anterior view of the right second maxilla, in order to show the muscles of the scaphognathite. The extensor muscles have been cut short, and the basal and inner portions of the scaphognathite have been opened in order to show the flexors and accessory muscles. × 1½. (To see this appendage in its natural position, the figure must be rotated to the left through an angle of 45°.)

Fig. 29. Posterior view of part of the first maxillipede of the right side, in order to show the muscles of the maxillipede and flabellum. The posterior flexor and the extensor muscles of the flabellum are cut through. × 2.

Fig. 30. Posterior view of the third maxillipede of the left side. The ventral walls of the various parts have been removed in order to display the muscles. × 1½. (The base of the appendage is to the left of the figure.)

Fig. 31. A dissection of the anterior part of the cephalothorax to display the muscles of that region. The dorsal portion of the carapace has been removed, and also the soft parts, with the exception of the muscles. × 2.

Fig. 32. Dissection of the female abdomen from the ventral side to display the extensor muscles. The ventral wall and appendages have been removed, as well as all the soft parts. × ½.

Fig. 33. Semi-diagrammatic longitudinal section through the abdomen of the female, to show the extensor and flexor muscles. × ½.

## Plate V.

Fig. 34. A dissection from above to display the various parts of the alimentary canal. The dorsal part of the body has been removed, as well as the gonads. The gills are not shown. The digestive gland is only shown on the left side.

Fig. 35. Vertical transverse section through the oesophagus, to show especially the oesophageal glands. × 35.

Fig. 36. Transverse section through the pyloric region of the fore-gut. × 30.

Fig. 37. Transverse section through a tubule of the digestive gland. × 120.

Fig. 38. A "fat cell" of the digestive gland. × 430.

Fig. 39. A "ferment cell" of digestive gland. × 430.

## Plate VI.

Fig. 40. The fore-gut from the left side, showing the ossicles. × 1½.

Fig. 41. The pyloric region of fore-gut, dorsal view. × 3.

Fig. 41*a*. Anterior view of the pro-pyloric ossicle. × 4.

Fig. 42. Transverse section through the region of the green gland, to show the parts of the bladder. Only one side shown. × 8.

Fig. 43. The ossicles of gastric mill, from above. × 2.

Fig. 44. The ossicles of the gastric mill, from below. The fore-gut has been opened ventrally. The left zygocardiac ossicle has been rotated in order to show the lateral teeth. × 3.

## Plate VII.

Fig. 45. The fore-gut from the left side, showing the intrinsic and extrinsic muscles. × 3.

Fig. 46. Anterior view of the fore-gut, to show the muscles. × 1½.

Fig. 47. The fore-gut from above, showing the intrinsic and extrinsic muscles. × 1½.

Fig. 48. The fore-gut from behind, showing the intrinsic and extrinsic muscles. The postero-lateral dilator has been cut near its insertion at the right side in order to show the antero-lateral dilator muscle. The right posterior dilator of the oesophagus has also been cut in order to expose the lateral dilators of oesophagus. × 3.

Fig. 49. Dorsal view of the heart. × 2.

Fig. 50. View of the heart from the left side. × 2.

## Plate VIII.

Fig. 51. General view of the blood system from above. The dorsal region of the carapace has been removed. On the right side the organs remain intact, but on the left side the ovary and digestive gland have been removed. One gill on the left side has also been turned outward in order to show the afferent branchial vein and the branchio-cardiac vein. In this region, also, the flabella of the second and third maxillipedes are seen lying beneath the gills. The course of the bladder is shown on the left side. × 1.

## Plate IX.

Fig. 52. View of ventral region of post-oral cephalothorax to show the sternal artery and its branches. All the muscles have been removed. On the right side the arteries going to the legs are cut short. The inferior abdominal artery is also cut short. × $\frac{1}{2}$.

Fig. 53. Dissection of abdomen from the dorsal side to show the superior abdominal artery. The tergal region of the abdomen has been removed. × 1.

Fig. 54. Dissection of the posterior region of the thorax to show the pericardium, heart, branchio-cardiac veins and efferent branchial veins. Only seven of the gills are shown on the left side, and on the right side only the roots of the

nine gills are shown. On the right side the epimeral wall has been removed in order to show the course of the branchio-cardiac veins, and also to show the connection between the latter and the pericardium. × 1.

Fig. 55. A dissection of the epimeral region of the thorax from the right side, in order to show the positions of the branchial sinuses, the infra-branchial sinus, the afferent branchial sinuses, and also the sinuses coming from the thoracic legs. × 1.

Fig. 56. Diagrammatic section through the thorax in the region of the heart, to show the blood system and the general arrangement of the organs. The tendons of the first walking legs are shown. × $\frac{1}{2}$.

## Plate X.

Fig. 57. Dissection of the left side to show the extensions of the bladder. The dorsal region of the carapace has been removed. The fore-gut has been cut through at the oesophagus and removed. The gonads and the digestive gland have also been taken away. The antennary gland is represented by a dotted circle. × 1.

Fig. 58. Semi-diagrammatic sagittal (vertical longitudinal) section of the antennary gland. The anterior part of the gland is to the right. × 60.

Fig. 59. Detailed drawing of part of previous figure, showing the epithelial cells of the bladder, end sac and the renal tubule. × 90.

Fig. 60. Section through the mass of cutaneous glands opening on to the epistoma. × 210.

Fig. 61. Section showing the epithelial cells of the mid-gut, with characteristic striated border. × 550.

Fig. 62. Longitudinal section through part of the wall of the hind-gut, about the middle of the abdomen, showing cutaneous glands. × 165.

Fig. 63. Dorsal view of the gills of the left side in their natural position, lying upon the thoracic epimera. The roofs of the branchial and prebranchial chambers have been removed. The scaphognathite has been turned over to the inner side, in order to show the maxillipedes. The flabellum of the first maxillipede is shown lying upon the gills (the longitudinal axis of the body is at an angle of 60° with the long axis of this plate). × 1.

Fig. 64. View of the branchial chamber of the left side. Each gill has been removed at its base, so that only the points of attachment of the gills are shown. The scaphognathite and first maxillipede (with flabellum) have been removed. By removing the gills the flabella of the second and third maxillipedes are exposed. × 1.

## Plate XI.

Fig. 65. Diagrammatic transverse section across a gill, showing the branchial septum, the afferent and efferent vessels and the lamellae. × 3.

Fig. 66. Longitudinal section through a gill in the region of the afferent vessel. × 100.

Fig. 67. Transverse section through a gill, to show especially the branchial excretory cells in the septum. × 24.

Fig. 68. A dissection of the nervous system from above. The alimentary canal has been cut through the region of the oesophagus and removed, but the stomatogastric system is shown. The nerves arising from the left side of the cerebral ganglia are alone shown. Those of the right side have been cut, only the nerves arising from the right side of the thoracic ventral mass are shown. The abdominal nerve is only shown as far as the anterior region of the abdomen. × 1.

Fig. 69. Longitudinal section through the eye. The optic ganglion is also shown. × 12.

Fig. 70. Enlarged drawing of two of the ommatidia from the previous figure. × 450.

Fig. 71. Transverse section across one of the ommatidia in the previous figure, through the rhabdome and retinulae. × 1000.

Fig. 72. Transverse section across one of the ommatidia in the previous figure, through the vitrella and the pigment cells. × 1000.

Fig. 73. Surface view of the cornea, showing one of the corneal facets. × 750.

Fig. 74. Olfactory seta taken from the exopodite of the first antenna. × 1100.

Fig. 75. Auditory seta ("hooked seta") from the auditory sac of the first antenna. × 400.

Fig. 76. Auditory seta ("group seta") from the auditory sac of the first antenna. × 300.

## Plate XII.

Fig. 77. Reproductive system of a fairly mature female, showing the double ovary, the spermathecae and the oviducts. × 1.

Fig. 78. Reproductive system of an immature male, showing the paired testes, the vas deferens and the ejaculatory duct. The fore-gut is also shown in position. × 2.

Fig. 79. Section through an almost ripe ovary, showing the eggs filled with yolk granules. The details are only inserted in one egg. × 190.

Fig. 80. A very early stage in the development of the embryo, attached to a seta of an endopodite of a female pleopod. This drawing shows the method of attachment. × 50.

Fig. 81. Ripe spermatozoon, showing the two processes. Taken from spermatheca of female. × 1400.

Fig. 82. Some of the epithelial cells of the bladder of the excretory system. The striated nature of the protoplasm is shown. × 650.

## Plate XIII.

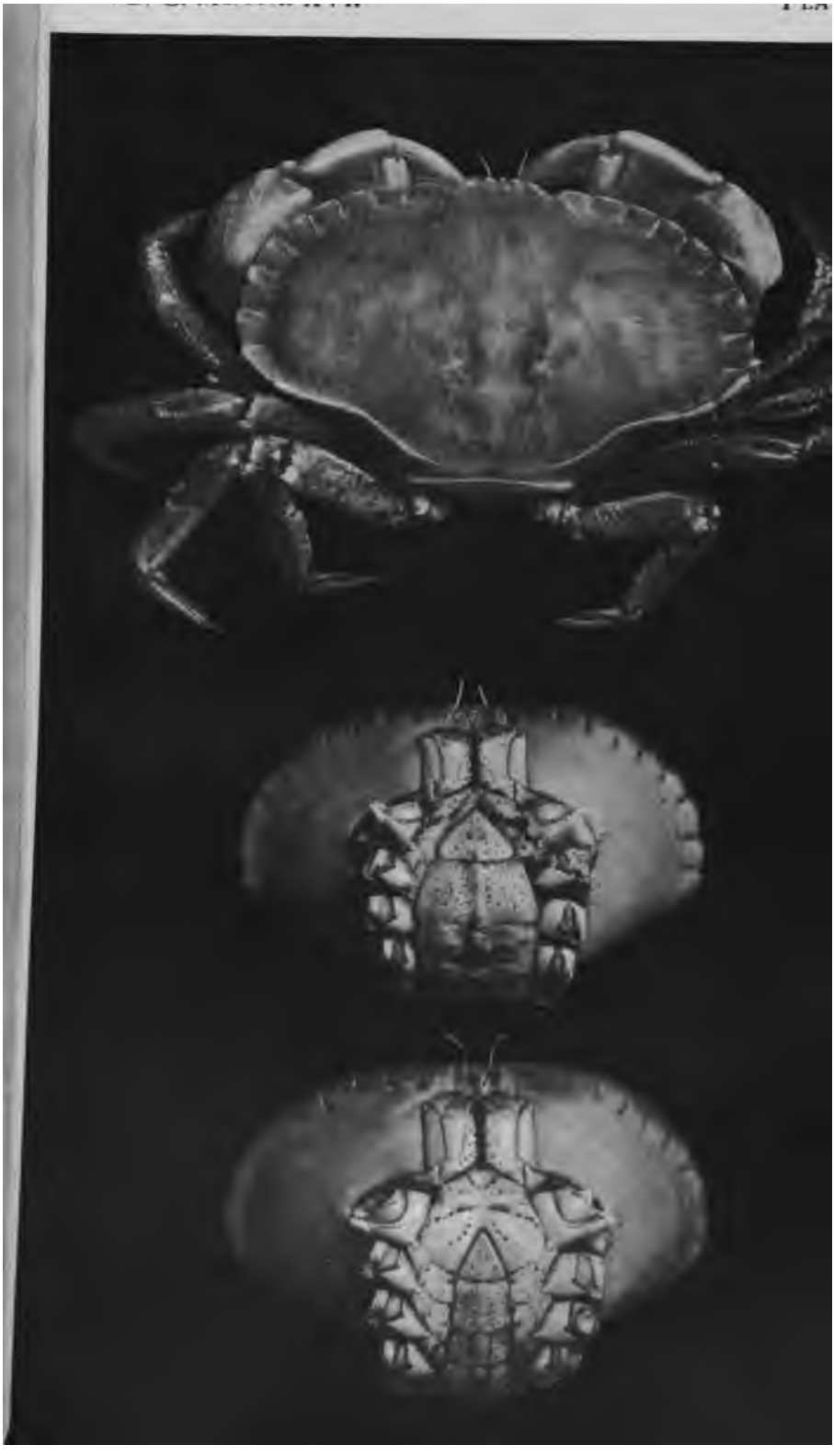
Fig. 83. Protozoëa of *Cancer pagurus*, two hours after hatching. View from the left side. × 120.

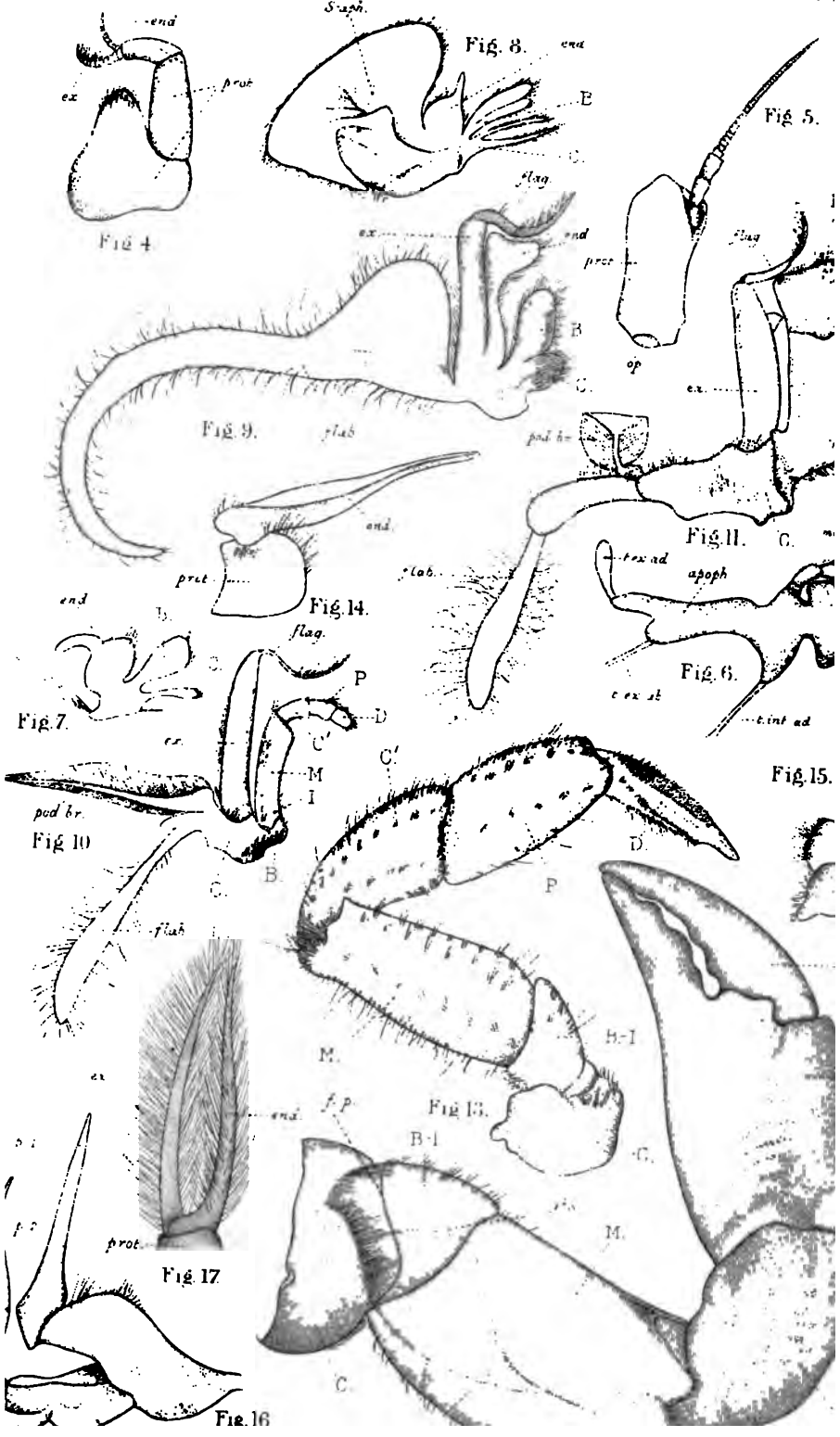
Fig. 84. Telson of the same stage, from above. × 175.

Fig. 85. Zoëa of *Cancer pagurus*, thirty hours after hatching, showing the maximum development of the frontal and dorsal spines. × 90.

Fig. 86. Dorsal view of the cephalothorax of the same stage. The dorsal and frontal spines are cut off short. × 110.

Fig. 87. Telson of the same stage, from above. × 160.

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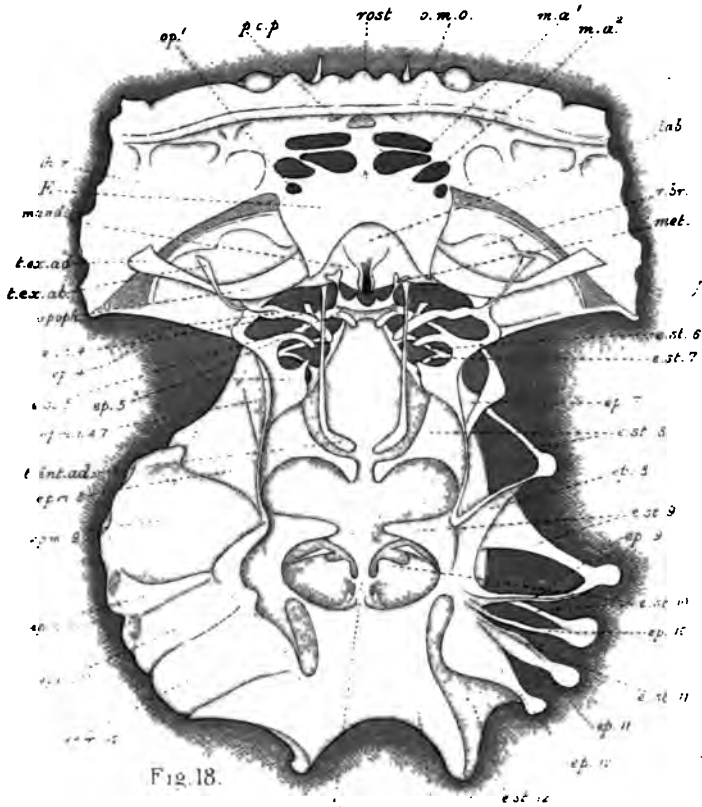
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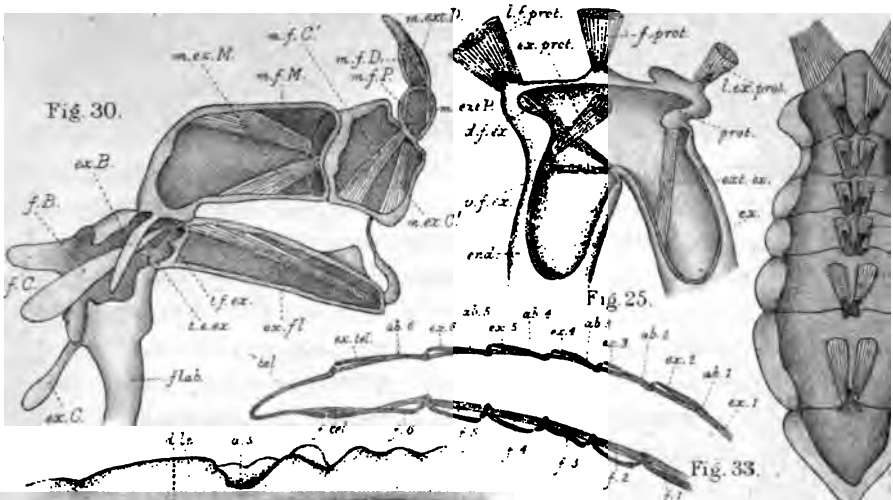
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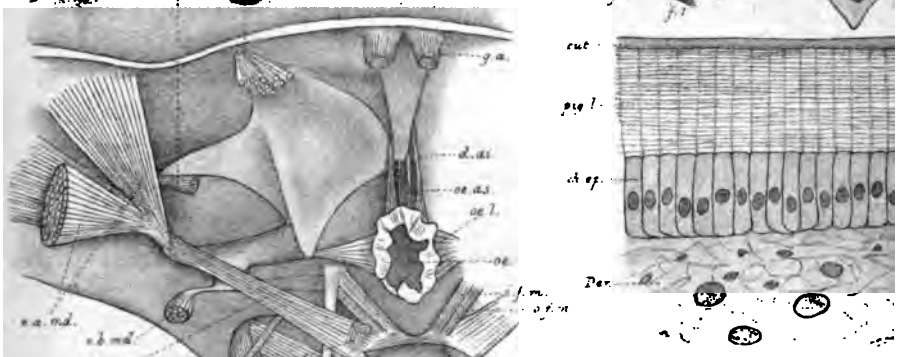
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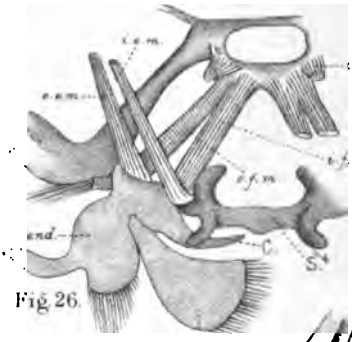
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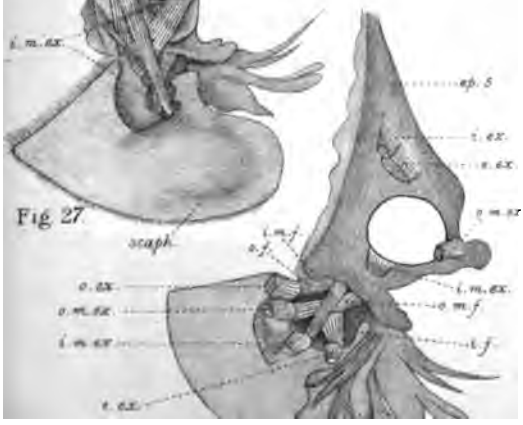
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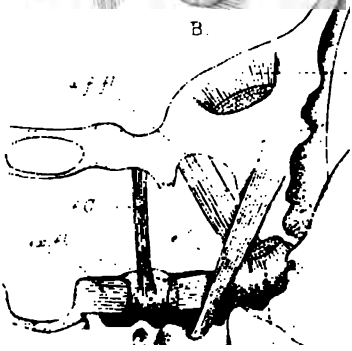
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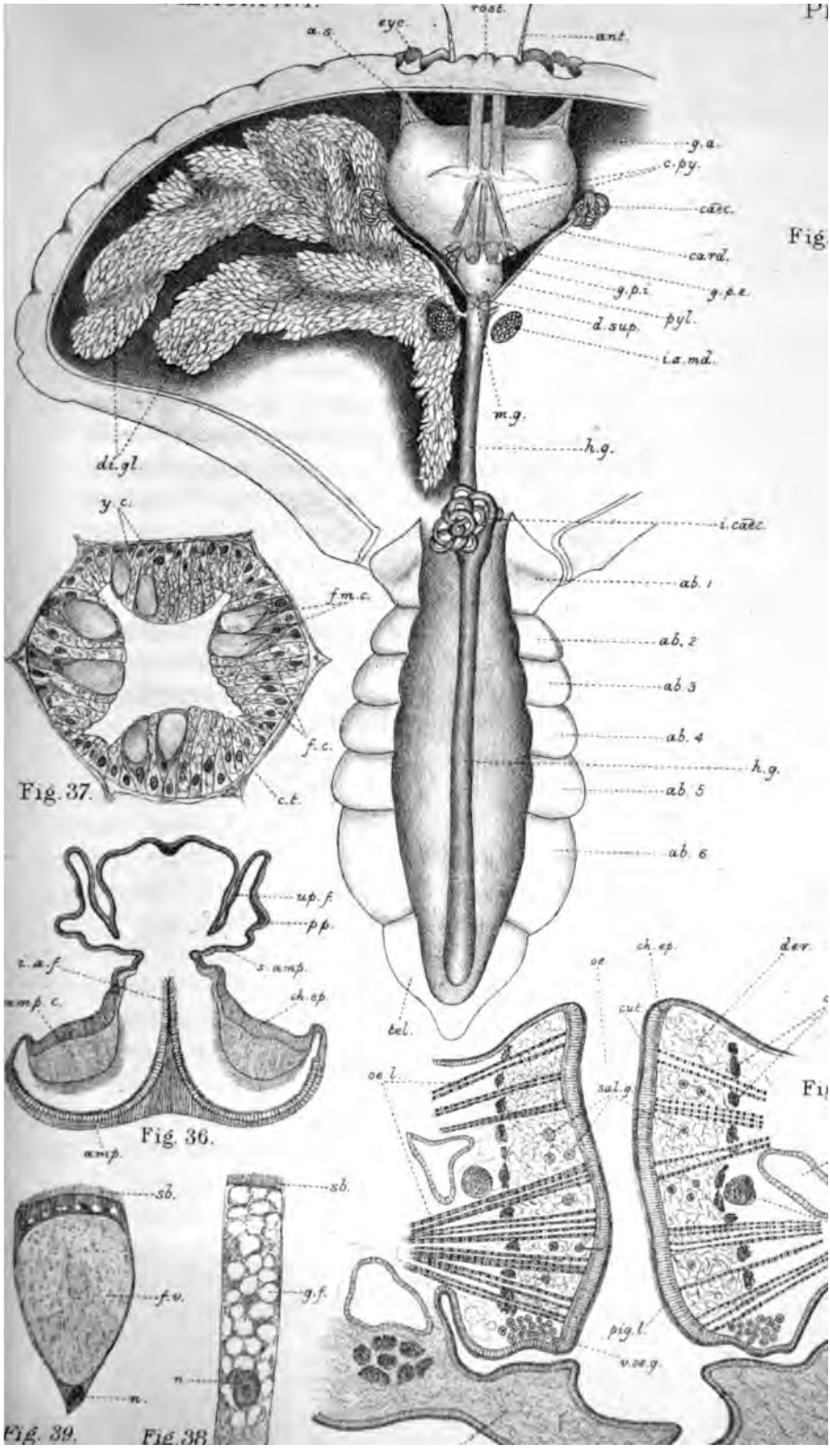
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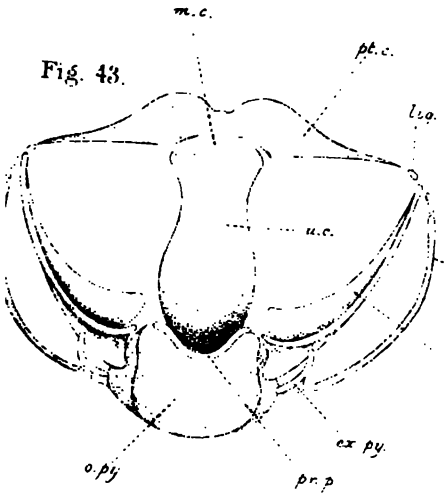
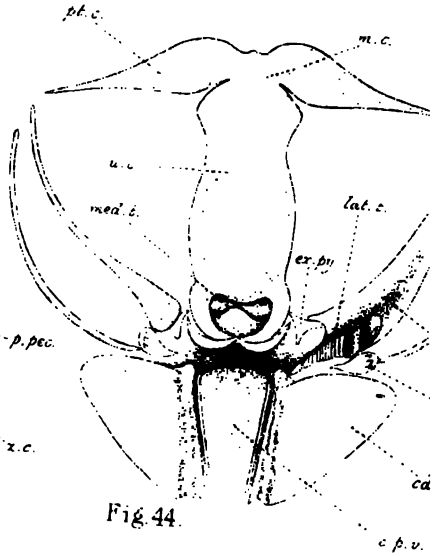
Fig. 43.

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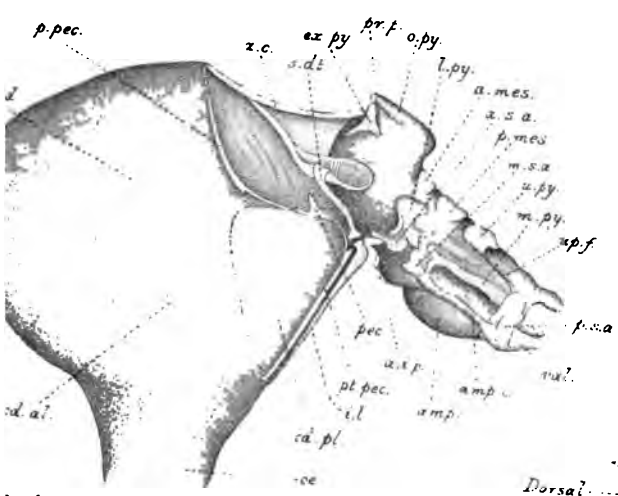


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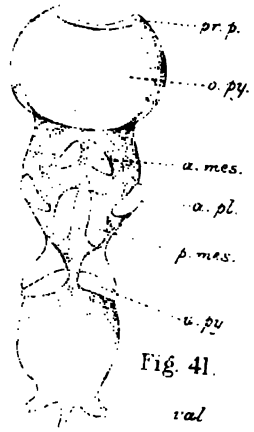


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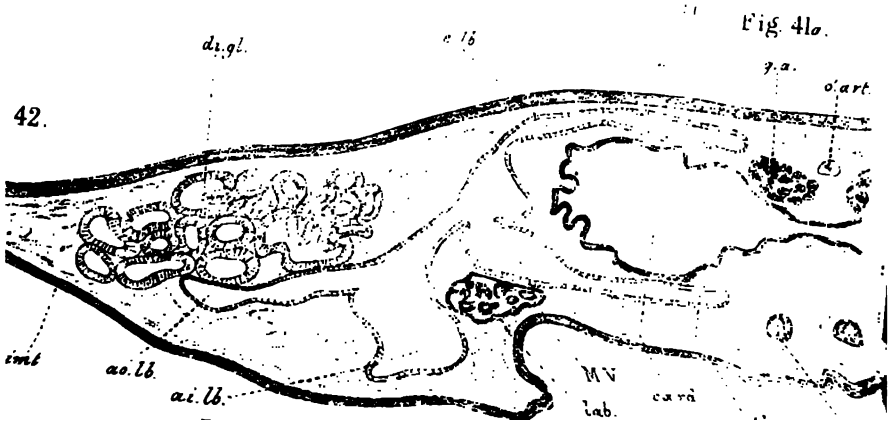
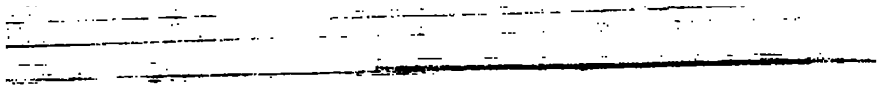
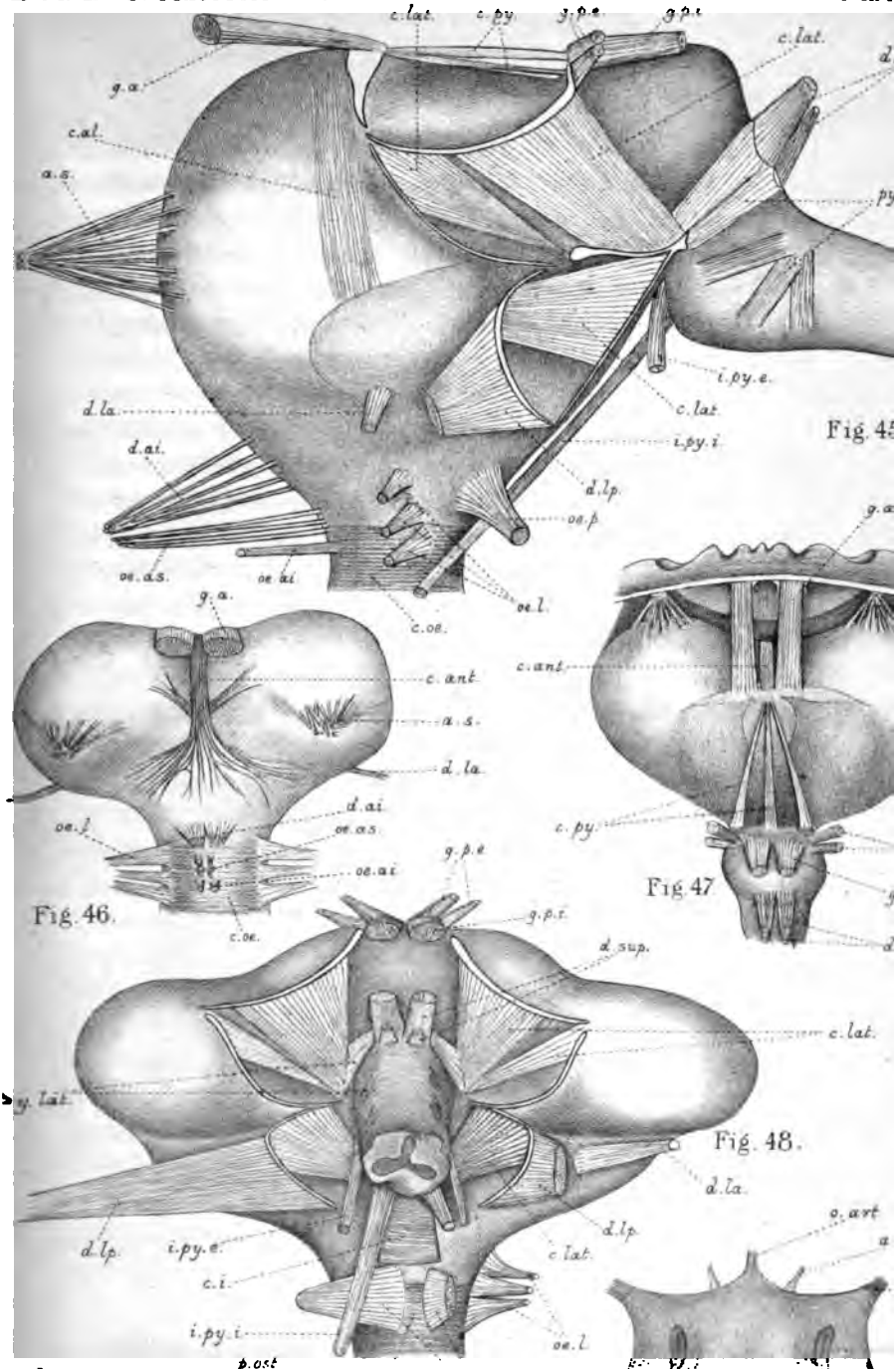



Fig. 41a.

42.

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c.al.
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i.py.e.
i.py.i.
d.lp.
oe.p.
oe.as.
oe.ai.
oe.l.
c.oe.
Fig. 45
g.a.
c.ant.
a.s.
d.la.
d.ai.
oe.as.
oe.ai.
oe.l.
c.oe.
Fig. 46.
Fig. 47
g.p.e.
g.p.i.
d.sup.
c.lat.
g.lat.
d.la.
d.lp.
i.py.e.
c.i.
i.py.i.
Fig. 48.
o.art.
cd.1
o.art.
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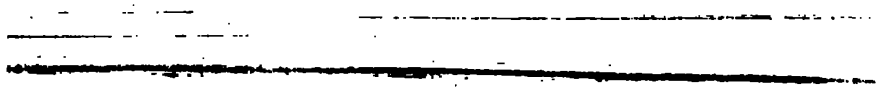
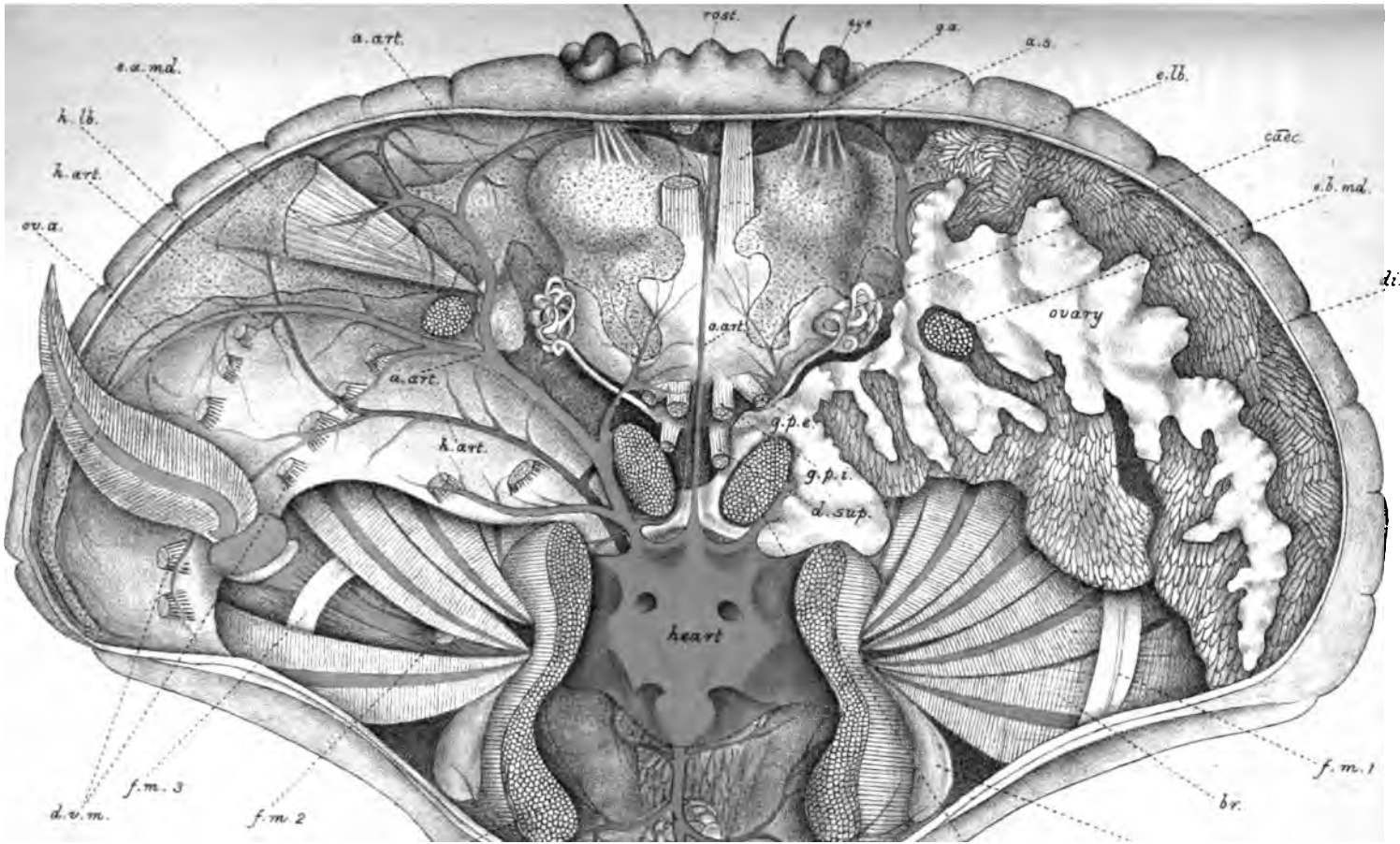
p.ost
cd.3
c.oe.
a.s
sa.art.
Fig. 50.
Fig. 49

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a.art.
g.p.e.
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heart
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f.m.2
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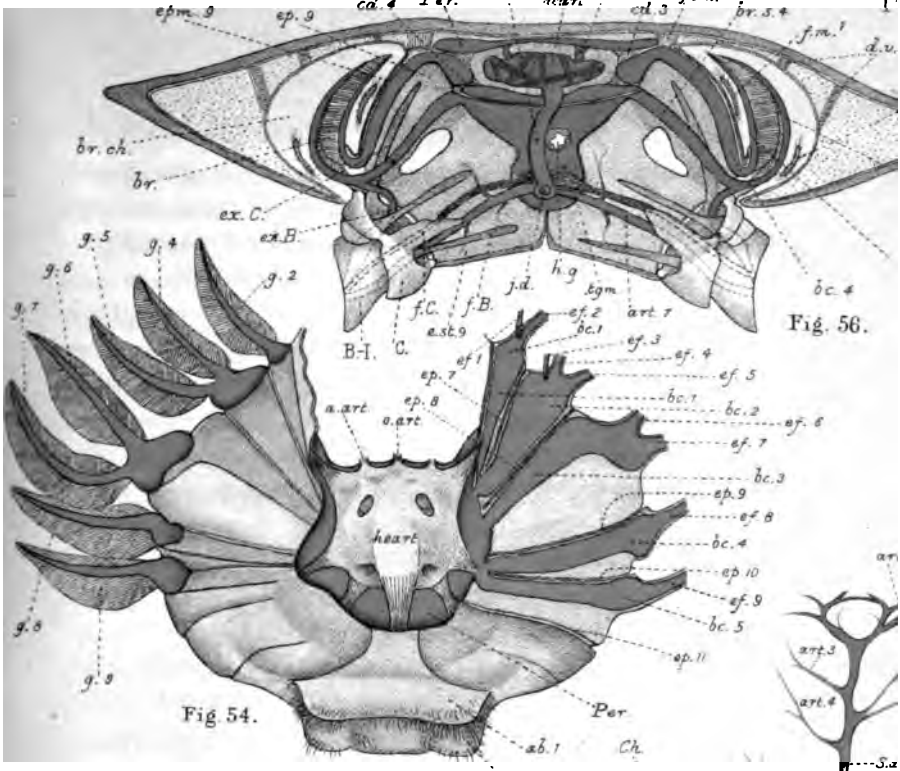
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g. 4
g. 6
g. 2
g. 7
f.C.
f.B.
j.d.
h.g
tgm
art. 7
bc. 4
e.st. 9
ef. 2
bc. 1
B-I.
C.
ef. 3
ef. 4
ef. 1
ep. 7
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a.art
ep. 8
a.art
bc. 1
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heart
ep. 9
ef. 8
bc. 4
ep. 10
ef. 9
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ab. 1
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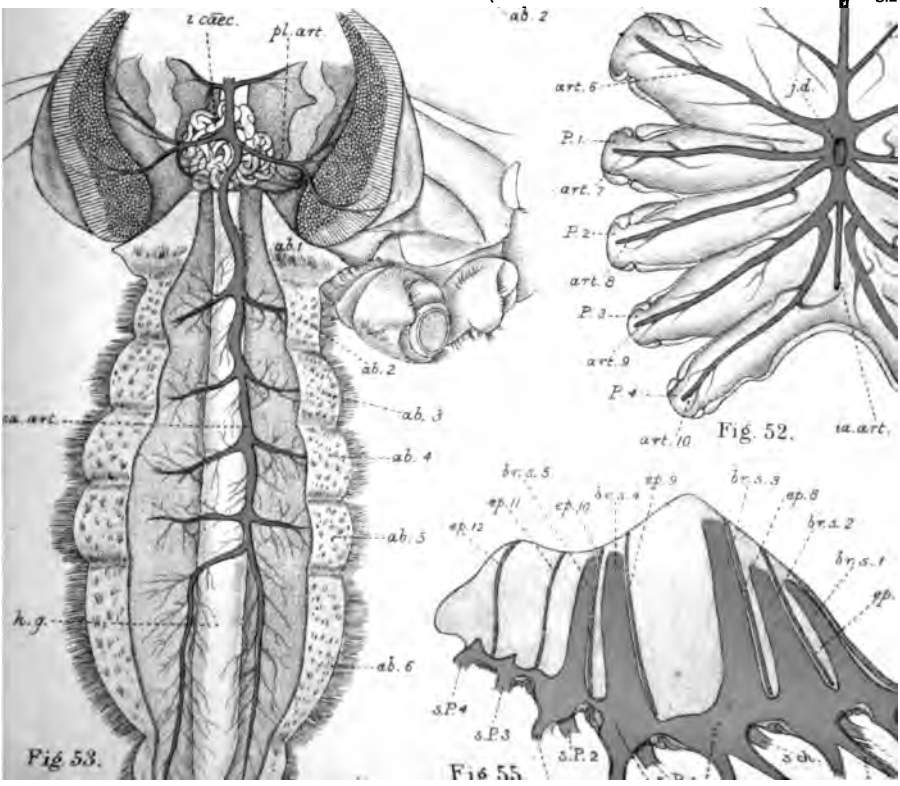
ab. 2
art. 3
art. 4
Fig. 54.
Fig. 56.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ab. 1
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ab. 5
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P. 1
art. 7
P. 2
art. 8
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art. 9
P. 4
art. 10
ta. art.
br. s. 5
ep. 11
ep. 10
br. s. 4
ep. 12
ep. 9
br. s. 3
ep. 8
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s.P. 2
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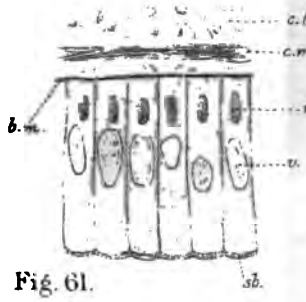
Fig. 53.
Fig. 55.
Fig. 52.

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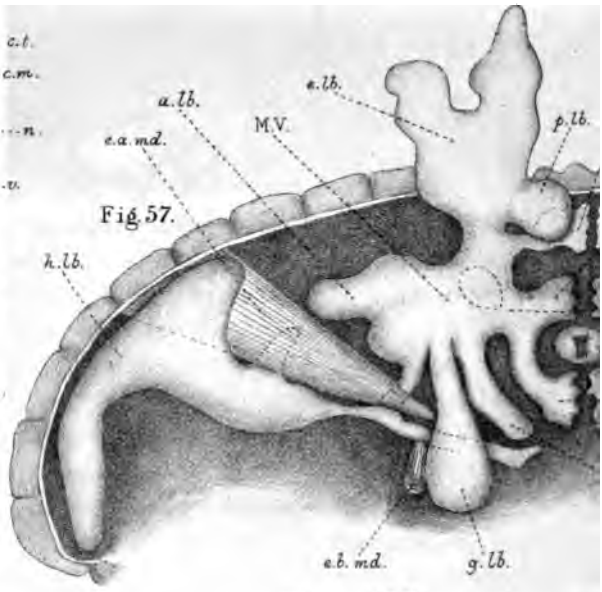


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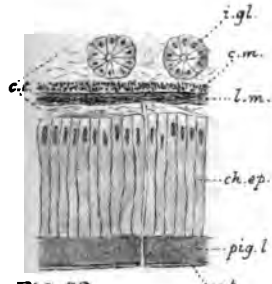


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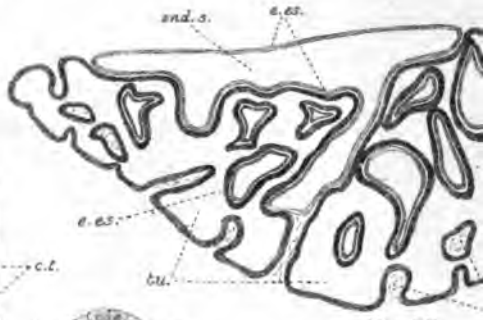


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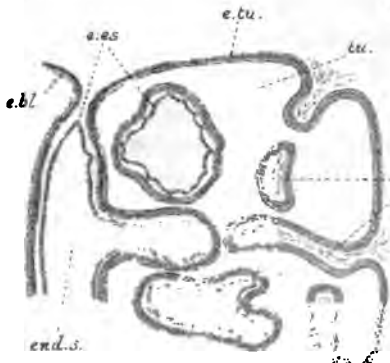


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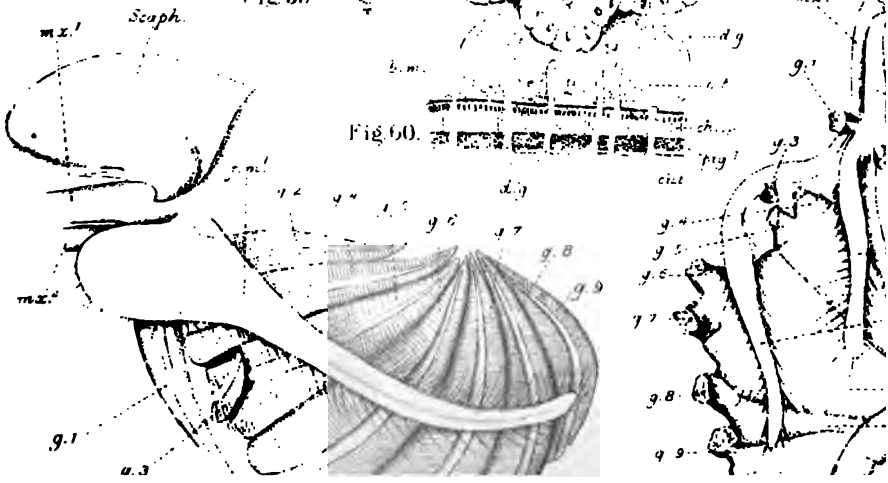


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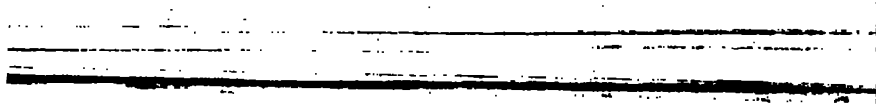


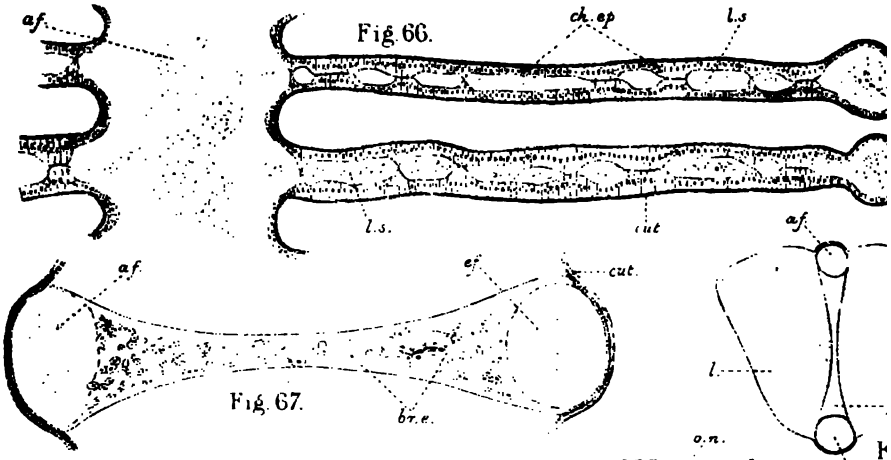



Fig. 66.

Fig. 67.

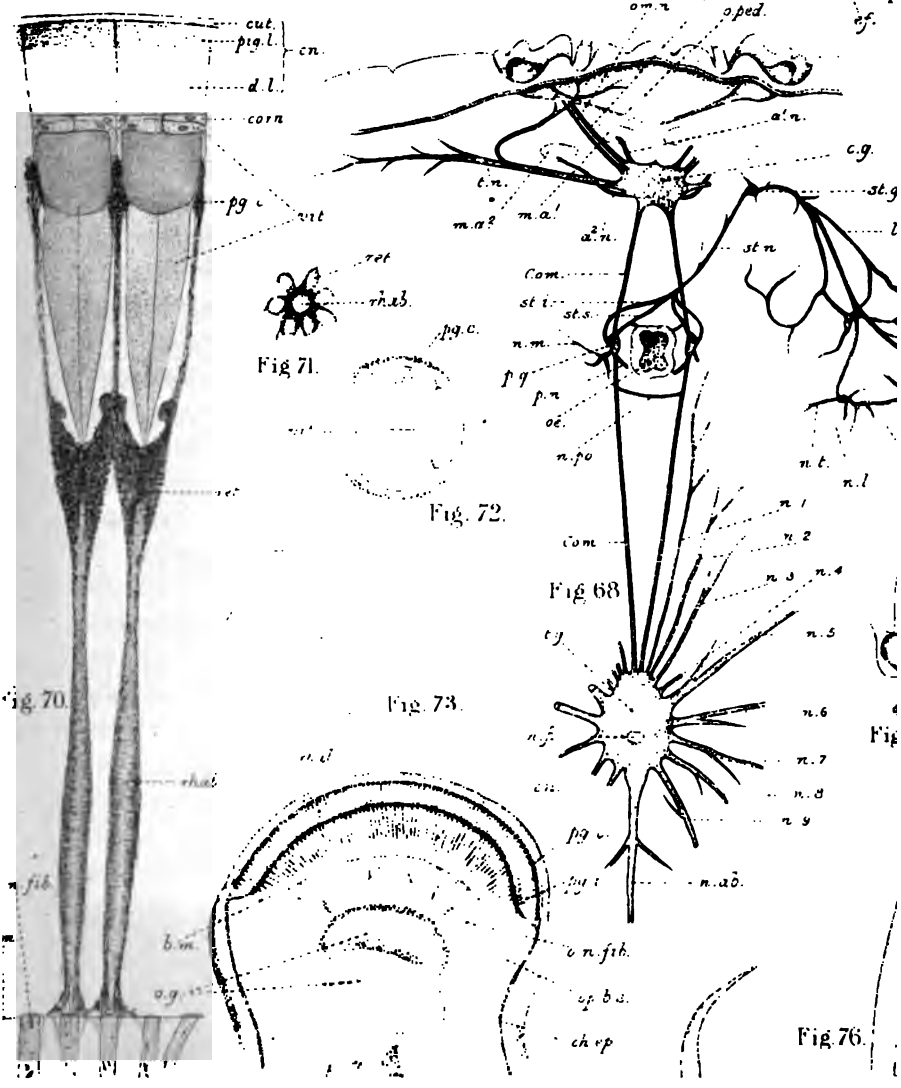



Fig. 71.

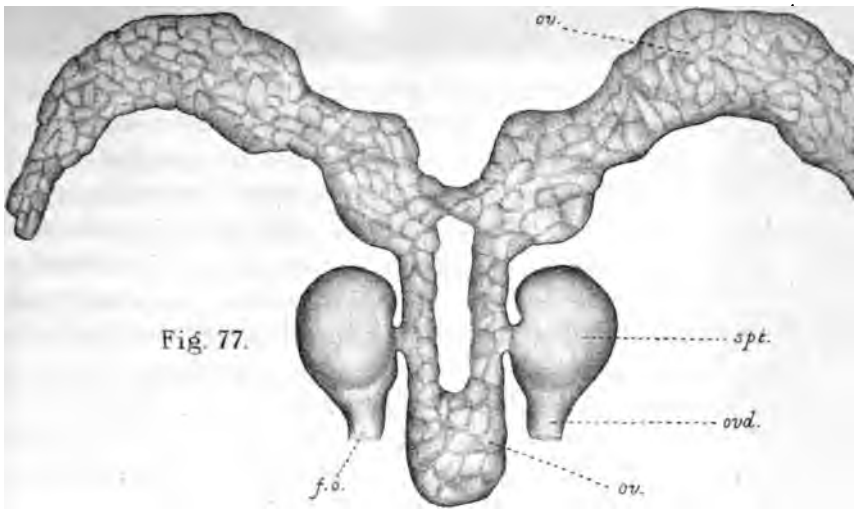
Fig. 72.

Fig. 68

Fig. 70.

Fig. 73.

Fig. 76.

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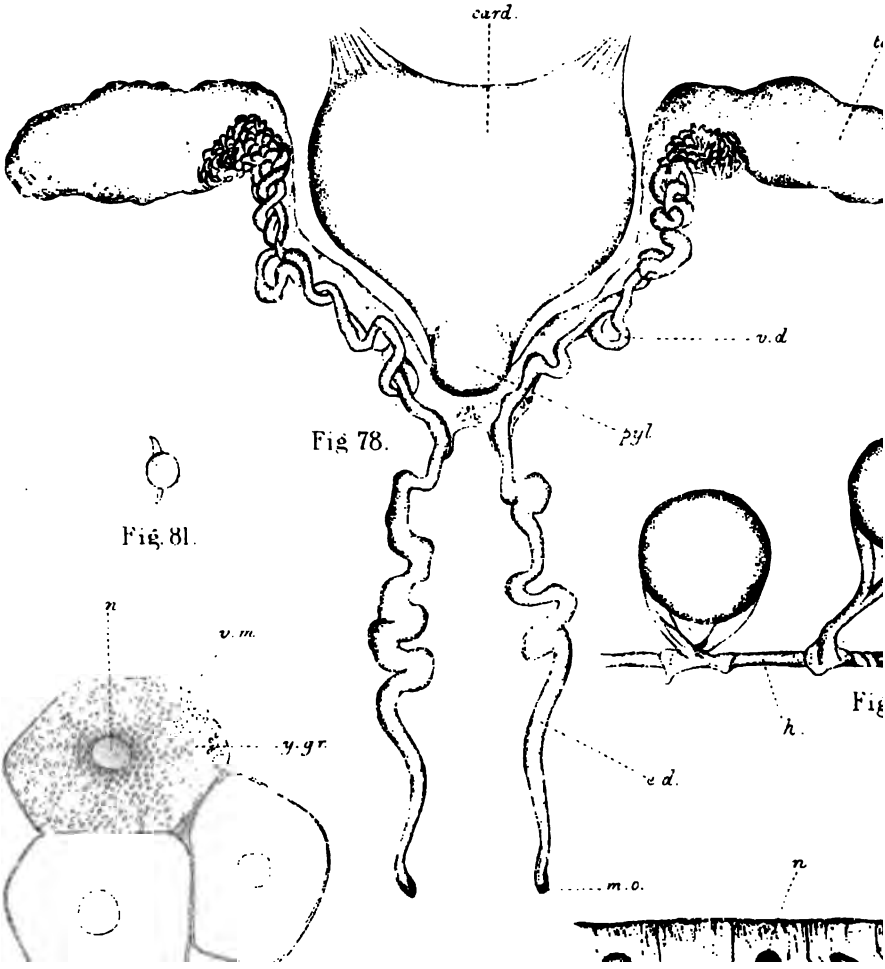
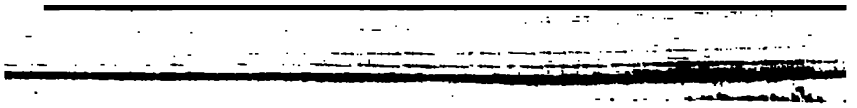



Fig 78.

Fig. 81.



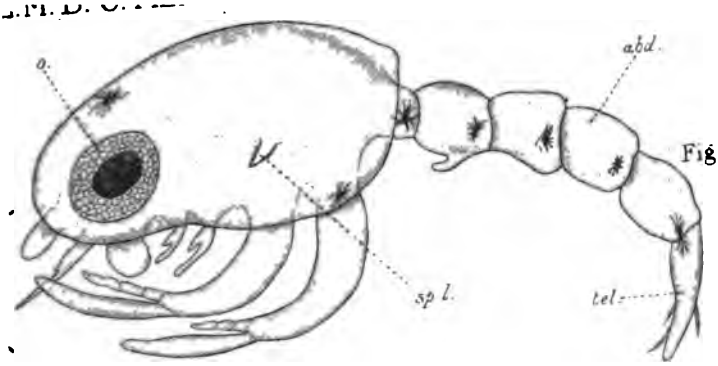
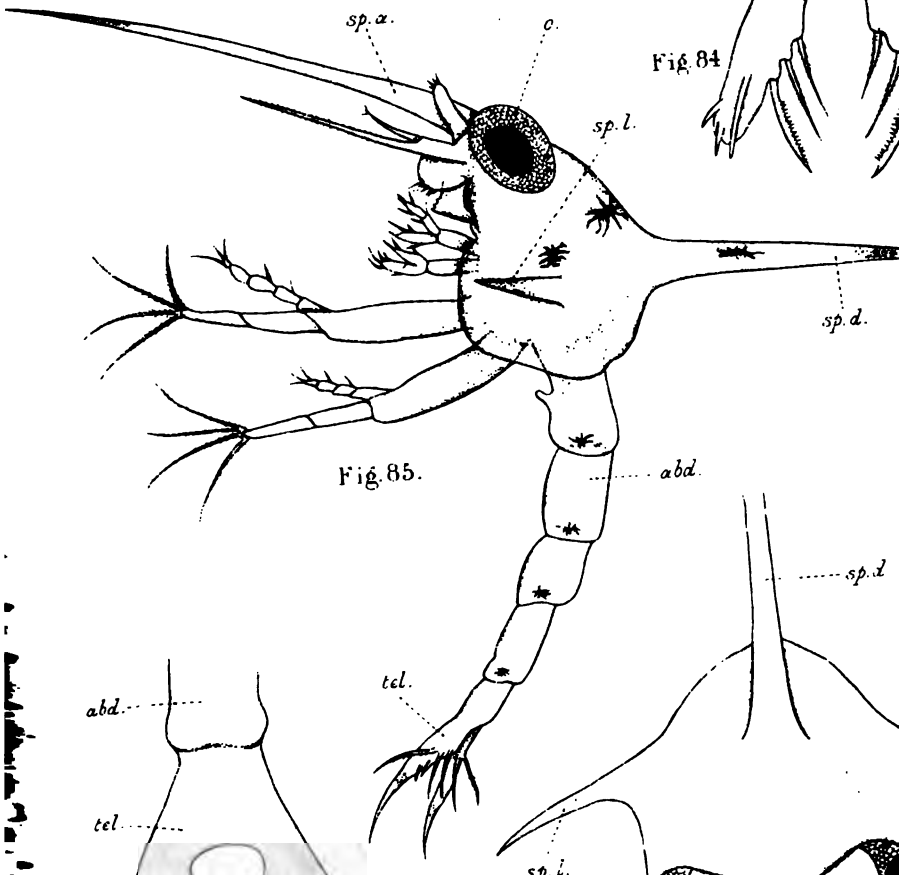



Fig. 83.

Fig. 84

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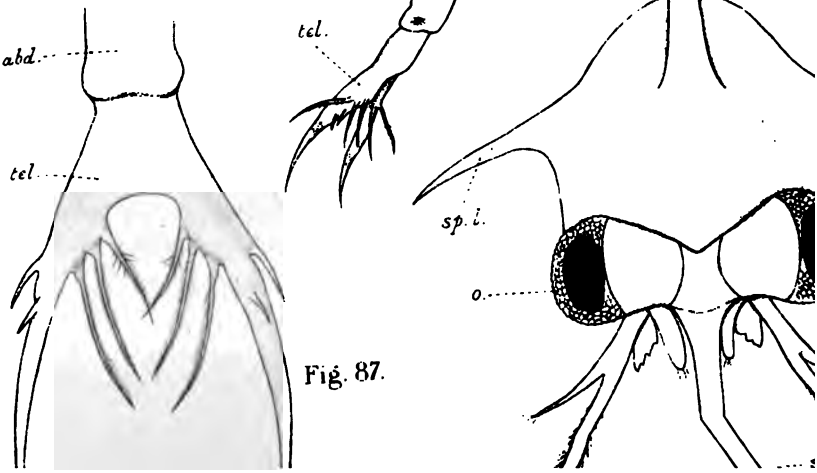

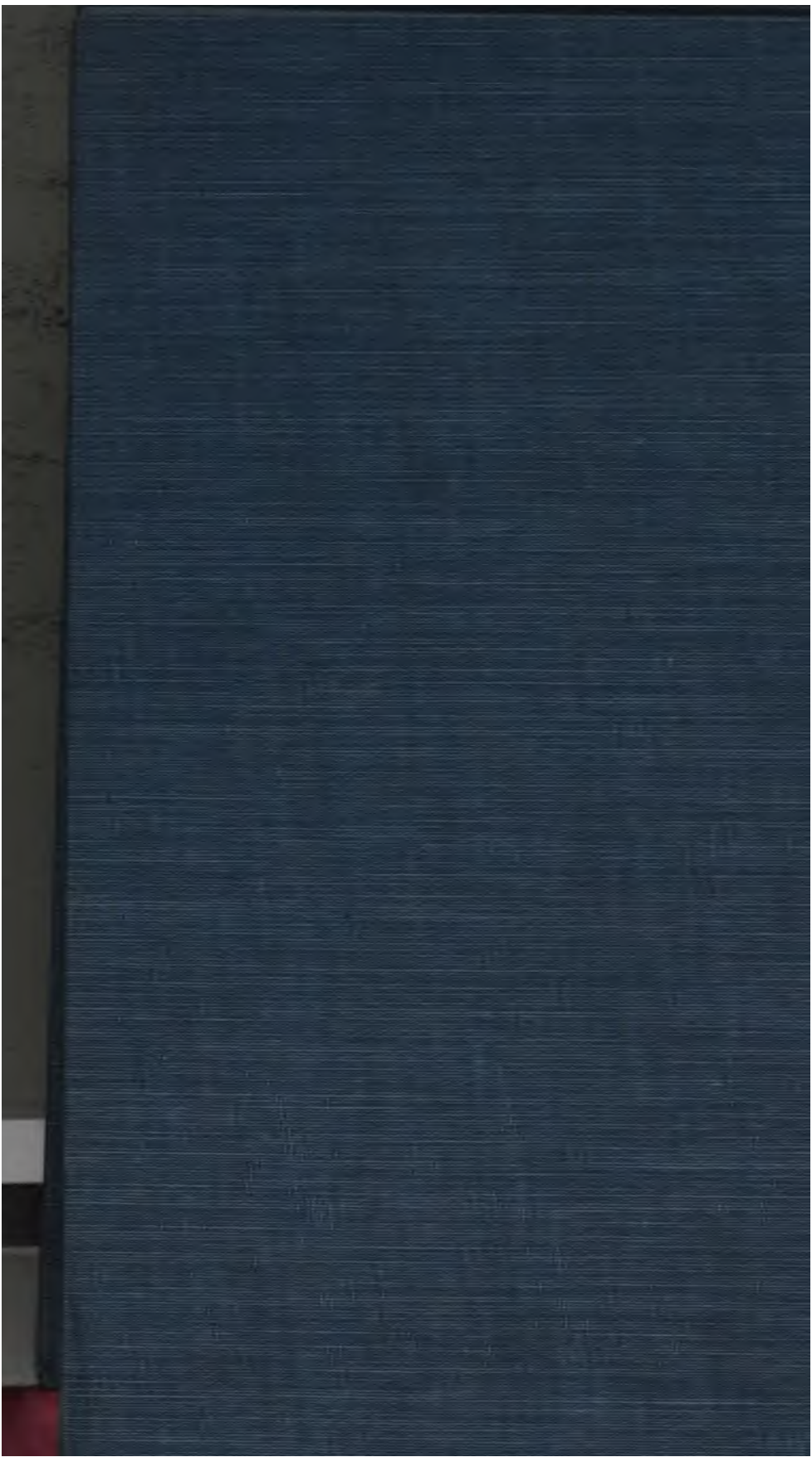
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